Biospheric Sciences

Biospheric Sciences, within the Laboratory for Terrestrial Physics, encompasses a broad range of basic and applied research to study terrestrial ecosystems and their interactions with the atmosphere using multi-scale remote sensing, modeling, and advanced analytical techniques. Experiments and investigations of a scientific nature utilizing Earth observations, new techniques and capabilities enhance our understanding of global processes for Earth System Science. For additional information see http://ltpwww.gsfc.nasa.gov/bsb/Home.html. Specifically, our Biospheric Sciences effort:

(1) Utilizes ground, aircraft, and satellite remote sensing instruments to measure variables that describe the temporal and spatial dynamics of natural ecosystems as well as human impacts on these systems, especially the vegetation condition (e.g., land cover, height, biomass, photo-synthetic capacity), soils (e.g., soil condition and type), and links to atmospheric constituents (e.g., aerosols, CO_2);

(2) Develops mathematical models which predict land surface conditions and processes related to rates of vegetation, soil, and atmosphere exchanges (e.g., radiation, heat, water, greenhouse gases, net primary productivity) as functions of remotely-sensed and ground-based observations;

(3) Acquires, produces, and distributes comprehensive, integrated land data sets incorporating ground, airborne, and/or satellite observations to facilitate model development and validation;

(4) Ensures the scientific integrity of new Earth remote sensing systems to improve space-based Earth observations by conducting calibration and validation studies and by serving as project managers and project and instrument scientists; and

(5) Performs basic research, which leads to the definition and development of new technologies, sensors, and missions to advance state-of-the art capabilities for monitoring global changes.

Through the above activities the Laboratory assesses and predicts environmental changes due to natural and anthropogenic processes at local to global scales to improve our understanding of global dynamics and processes occurring on the land, in the oceans, and in the lower atmosphere. Past studies include assessment of deforestation, desertification, land use, land cover, vegetation anomalies, primary productivity, famine early warning, biomass burning, ecologically-influenced pests and diseases, and the extent and impact of urbanization. In this report the Biospheric Sciences projects are organized under four sub-categories: **Research, Data Processing, Satellite Programs, and International Programs.**

Biospheric Sciences Research

The primary responsibility of the Biospheric Sciences discipline is to facilitate the use of remote sensing to measure, monitor and understand the ecology of the Earth through research into remote sensing techniques.

AERosol RObotic NETwork (AERONET)

Goddard's ground-based AERosol RObotic NETwork (AERONET) program provides measurements of column integrated aerosol optical, microphysical and radiative properties. The original program was developed from the requirement to remove aerosol effects on remotely sensed imagery of the surface. Over the past decade, the need shifted to validation of satellite retrievals of aerosol optical thickness and more recently aerosol characterization due to the advanced retrievals of climate sensitive particle size and absorption characteristics (single scattering albedo). The decadal growth to almost 150 permanent sites distributed on every continent and a variety of island sites provides a unique opportunity to characterize aerosol properties on several scales. Summarized below is a regional investigation of biomass burning aerosol as measured by AEROENT during the southern African biomass burning season of 2000, followed by the first global assessment of the climatically important single scattering albedo using the widely distributed AERONET sites over years of observations (Dubovik, et al., 2002).

Measurements of the column-integrated aerosol optical properties in the southern African region were made by AERONET sun-sky radiometers at several sites in August-September 2000 as a part of the SAFARI 2000 dry season field campaign. Fine mode biomass burning aerosols dominated in the northern part of the study region (Zambia), which is an active burning region. Other aerosols including fossil fuel burning, industrial, and aeolian coarse mode types also contributed the aerosol mixture in other regions (South Africa and Mozambique), which were not as strongly dominated by local burning. The large amount of smoke produced in the north lead to a north-south gradient in aerosol optical depth (τ_a) in September, with biomass burning aerosol concentrations reduced by dispersion and deposition during transport. Large average diurnal variations of τ_a(typical diurnal range of 25%) were observed at all sites in Zambia as a result of large diurnal trends in fire counts in that region that peak in mid-afternoon. However, for all sites located downwind to the south, there was relatively little (~5-10%) average diurnal trend observed as the aerosol transport is not strongly influenced by diurnal cycles. AERONET radiometer retrievals of aerosol single scattering albedo (ω_0) in Zambia showed relatively constant values as a function of τ_a, for τ_{a440} ranging from 0.4 to ~2.5. The wavelength dependence of ω_0 varied significantly over the region, with greater decreases for increasing wavelength at smoke dominated sites than for sites influenced by a significant coarse mode aerosol component. Retrievals of mid-visible ω_0 based on the fitting of Photosynthetically Active Radiation (PAR; 400-700 nm) flux measurements to modeled fluxes for smoke in Mongu, Zambia yielded an average value of 0.84. This is in close agreement with the estimated average of 0.85 derived from interpolation of the AERONET retrievals made at 440 and 675 nm, for August-September, 2000. The spectral dependence of ω_0 independently retrieved with the AERONET measurements and with diffuse fraction measurements in Mongu, Zambia was similar for both techniques, as a result of both methods retrieving the imaginary index of refraction (~0.030-0.035 on one day) with very little wavelength dependence. Constant imaginary refractive index as a function of wavelength is consistent with soot being the primary component of aerosol absorption.

Although the biomass burning aerosol optical properties measured at several sites in Zambia during August-September 2000 were relatively uniform, over the broader southern Africa region the observations suggest significant aerosol variability. The observed regional differences in aerosol single scattering albedo and size distributions, due to aerosol aging during transport and from contributions by other aerosol sources (i.e. aeolian dust, fossil fuel combustion aerosols, etc.), need to be considered when assessing regional aerosol radiative forcings and retrieval of aerosol properties from satellite. Aerosol optical properties also change seasonally in some southern Africa locations and this aspect of regional aerosol dynamics is being examined in another study.

Dubovik used eight years of globally distributed data from AERONET to produce a climatology of aerosol optical properties. Using Dubovik and King's comprehensive inversion, these data resulted in the development of robust models of real undisturbed aerosol in the total atmospheric column and, for the first time, allowed quantitative differentiation of both the magnitude and spectral dependence of the absorption of aerosol in locations with varying emission sources and conditions. These reported data agree with known aerosol information in general; however they reveal several important differences for each type of aerosol.

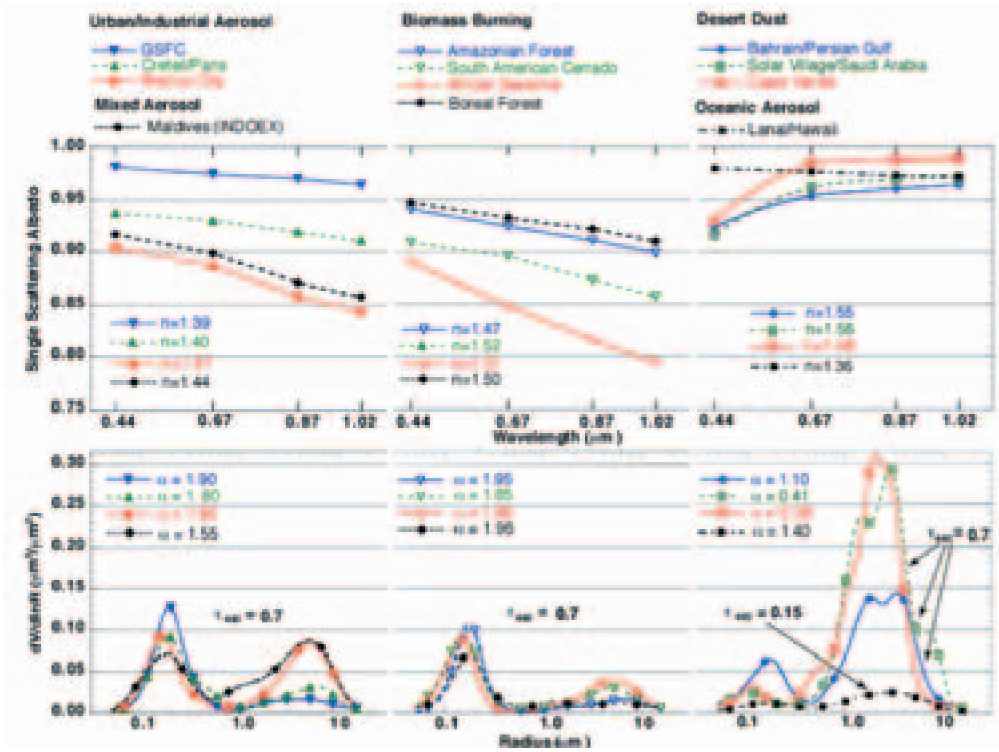

Figure 1. The averaged optical properties of different types of tropospheric aerosol retrieved from the global AERONET network of ground-based radiometers. Urban/industrial, biomass burning and desert dust aerosols are shown for $\tau_{ext}(440) = 0.7$. Oceanic aerosol is shown for $\tau_{ext}(440) = 0.15$ since oceanic background aerosol loading does not often exceed 0.15. Ångström parameter τ is estimated using optical thickness at two wavelengths, 440 and 870 nm.

For example, Dubovik et al. found that:

- In contrast to most aerosol models, and in agreement with analysis of satellite data, desert dust absorption of solar radiation is weak for wavelengths greater than 550 nm (ω_0 ~ 0.96 – 0.99). However dust exhibits a pronounced absorption in the blue spectral range ($\omega_0(440)$ ~ 0.92 – 0.93).

- Smoke absorption is related to the vegetation type burned and relative contribution of the flaming and smoldering combustion phases. Boreal and Amazonian forest fire smoke absorbs distinctly less ($\omega_0(440)$ ~ 0.94) than grassland dominated smoke from African savanna ($\omega_0(440)$ ~ 0.88) and mixed source smoke at South American cerrado sites ($\omega_0(440)$ ~ 0.91).

- Absorption for urban/industrial aerosol varies from almost no absorption ($\omega_0(440) \sim 0.98$) at GSFC (East Coast of U.S.) to significant absorption in places with high level of industrial pollution: $\omega_0(440) \sim 0.90$ in Mexico City and $\omega_0(440) \sim 0.89$ for near the Indian subcontinent. Aerosol over Paris shows an intermediate level of absorption ($\omega_0(440) \sim 0.93 – 0.94$).

References:

Dubovik, O., B.N. Holben, T.F. Eck, A. Smirnov, Y.J. Kaufman, M.D, King, D. Tanre, and I. Slutsker, Variability of absorption and optical properties of key aerosol types observed in worldwide locations, J. Atm. Sci., 59, 590-608, 2002

Eck, T.F., B.N. Holben, D.E. Ward, M.M. Mukelabai, O. Dubovik, A. Smirnov, J.S. Schafer, N.C. Hsu, S.J. Piketh, A. Queface, J. Le Roux, R.J. Swap and I. Slutsker, Variability of biomass burning aerosol optical characteristics in southern Africa during the SAFARI 2000 dry season campaign and a comparison of single scattering albedo estimates from radiometric measurements, J. Geophys. Res., accepted, 2003.

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Carbon Cycle

Interannual Variability in the Terrestrial Carbon Cycle

Measurements of the concentration of CO_2 in the atmosphere show that fossil fuel burning is causing CO_2 to increase and also that significant CO_2 sinks (anthropogenic input exceeds observed atmospheric increases) exist which vary in magnitude from year to year. Given the scale of these changes in the composition of the atmosphere and the potential effects on climate the international science community has focused much attention on improving the understanding of the processes responsible for carbon sources and sinks (Intergovernmental Panel on Climate Change, 2001, Chapter 3).

On average about half of the CO_2 emitted to the atmosphere through fossil fuel burning and deforestation each year remains in the atmosphere. The oceans and land surfaces absorb the rest but large uncertainties exist as to the mechanisms responsible for this net sink. This sink varies from year to year between 0 to nearly all of the emitted CO_2. The relative contributions of ocean versus land processes can be disentangled using atmospheric $^{13}C/^{12}C$ measurements in conjunction with CO_2 measurements. This is because the important CO_2 exchange process on land is C_3 photosynthesis which discriminates strongly against $^{13}CO_2$ while air-sea CO_2 exchange is controlled by physical processes that produce less discrimination. Results from recent studies using this technique show that the land surface is responsible for about half the total sink and may be responsible for most of the interannual variability in the atmospheric CO_2 growth rate. However, the estimated magnitude of the land sink is sensitive to a number of assumptions, such as, 1) the contribution of C_4 plants to terrestrial production and 2) covariance in the response of plant productivity and $^{13}CO_2$ discrimination to drought.

In a collaborative effort between scientists from California Institute of Technology and Carnegie Institution of Washington, aspects of the interpretation of the atmospheric isotopic composition were addressed. In addition, this effort explored the role of fire in determining interannual variability in the atmospheric CO_2 growth rate.

Contributions of C_4 photosynthesis to terrestrial primary productivity and atmospheric $\delta^{13}C$

The global distribution of the fractional coverage of C_4 plants can be predicted from satellite derived vegetation classification maps, crop inventory data bases and models of climate controls on photosynthesis (Figure 2). C_4 plants naturally occur and are largely restricted to tropical and subtropical regions though C_4 crops such as corn are grown in more temperate climates. C_4 photosynthesis is almost completely restricted to herbaceous forms of vegetation and therefore, is less prominent in closed canopy forests such as tropical rain forests. Using the map and productivity models, it is estimated that C_4 photosynthesis is about1/3 of annual global C_3 photosynthesis. By including the impact of C_4 photosynthesis on the atmospheric $\delta^{13}C$, the estimated terrestrial carbon sink inferred from atmospheric measurements is 60% larger than if photosynthesis is neglected (Still et al., 2003). Longer term climate driven changes in the distribution of C_4 relative to C_3 plants will likely influence atmospheric $\delta^{13}C$.

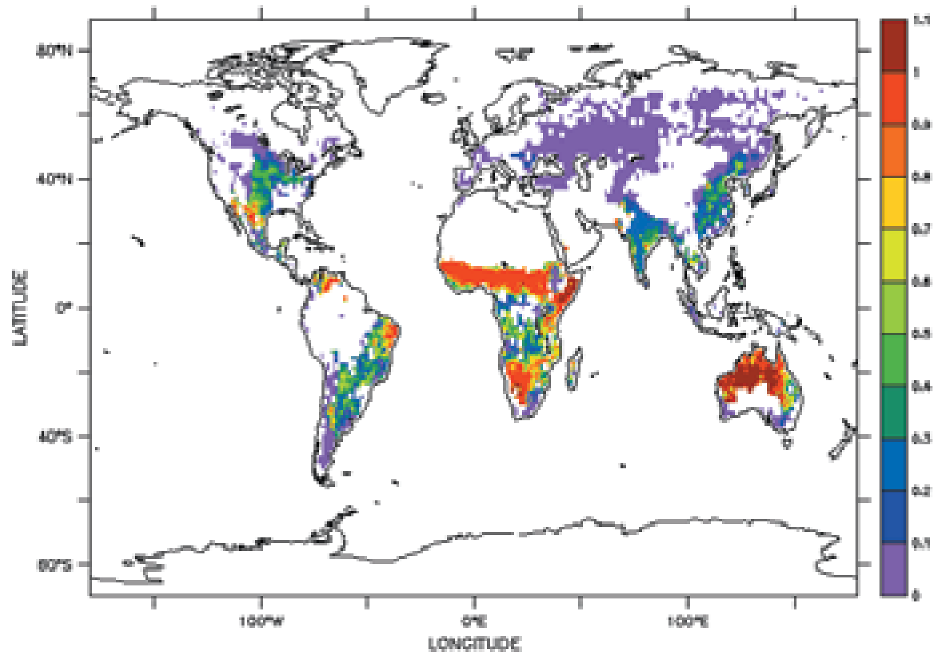

Figure 2. Map of the fraction of vegetation in each pixel that possesses the C_4 pathway.

Impacts of Drought on Estimating Land Sinks from Atmospheric $\delta^{13}C$

The strong discrimination by C_3 plants (the dominant type globally) against $^{13}CO_2$ produces a measurable signal in atmospheric $\delta^{13}C$ that is used to estimate the terrestrial contribution to the observed variations in atmosphere CO_2 concentrations. C_3 discrimination by individual plants has been shown to vary, however, in response to atmospheric humidity and drought. Global drought episodes associated with the ENSO cycle might be expected to affect inferences about the size of terrestrial carbon sink that are based on atmospheric $\delta^{13}C$ and CO_2 concentration measurements. Ecophysiological and biogeochemical models were used to estimate the magnitude of the impact of climate variability on inferred carbon sinks (see Randerson et al., 2002 on Refereed Publication list). Small changes in discrimination caused by drought were found to have a large impact on inferred terrestrial sinks because the decrease in discrimination caused by drought is associated with decreases in gross primary production. The results imply that previous analyses that ignored this effect overestimated interannual variability in global carbon sinks (Figure 3).

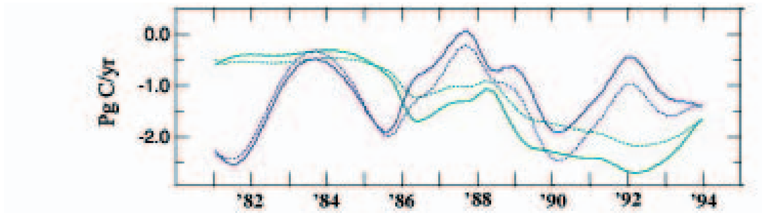

Figure 3. Interannual variability in the atmospheric carbon flux anomalies associated with the land and the ocean (negative denotes sink). Net fluxes from the land to the atmosphere are indicated in blue and from the ocean in green. Solid lines are for simulations in which the drought impacts are ignored and dotted lines for drought impacts included.

Fire

Analysis of the interannual variability in the rate at which global atmospheric CO_2 is increasing shows intriguing correlations with ENSO cycles. During El Nino phases the growth rate is larger than intervening periods. Other analyses indicate that this variability is largely a result of carbon fluxes associated with land processes. The explanations for these phenomena have for the most part focused on the impacts of climate on the balance between photosynthesis and respiration on land. For instance, the drier, warmer conditions in the tropics during El Nino causes inhibition of photosynthesis and/or stimulation of respiration producing a net sink anomaly at the global scale. Recently, it has been argued that much of the net land source is the result of increased wild fires associated with El Nino conditions. In particular during the strong El Nino of 1998 when the atmospheric sink was near zero large fires occurred in Indonesia and in northern boreal forests. These arguments are based on atmospheric observations and there are no published direct observations of the global distribution and magnitude of fire emissions.

Using fire counts from the VIRS instrument on board TRMM that were calibrated with burned area estimates from MODIS scenes, a time series of burned area has been constructed within the TRMM footprint (30S-38N, where 90% of global fires occur) for the period 1998 to the present. Figure 4 shows the % of area in each grid cell that burned per year averaged from 1998-2001. A biogeochemical model of biomass production and decomposition has been modified to include fire mortality and fuel consumption. Using the burned area maps as input to the model, seasonality and interannual variability in carbon emissions from fire can be predicted (van der Werf et al., 2003). Early results support the proposition that fires are largely responsible for the large increase in the growth rate of atmospheric CO_2 in 1998. Currently this analysis is being extended to the entire globe.

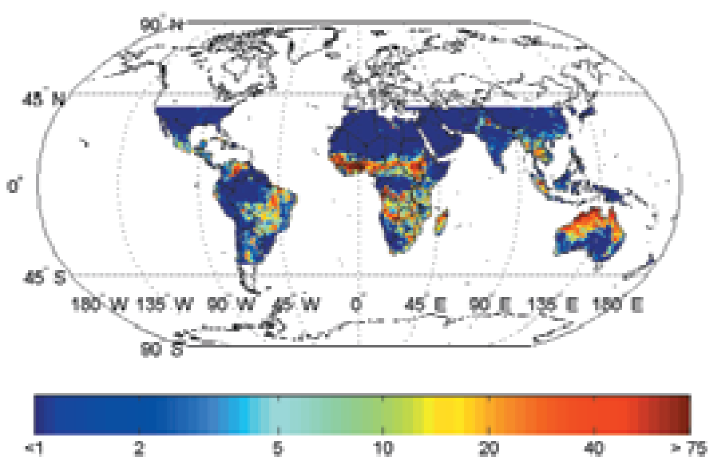

Figure 4. % of pixel area burned per year averaged for 1998-2001.

References:

Still, C. J., J. A. Berry, G. J. Collatz, and R. S. DeFries, Global distribution of C_3 and C_4 vegetation: Carbon cycle implications. Global Biogeochemical Cylces 17, 1006, doi:10.1029/2001GB001807, 2003

van der Werf, G. R., J. T. Randerson, G. J. Collatz, and L. Giglio, Carbon emissions from fires in tropical and subtropical ecosystems, Global Change Biology (accepted), 2003.

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Measuring Human Impacts on Biodiversity and Carrying Capacity of Ecosystems

As we begin to recognize the scope of human influence on Earth's ecosystems, it is important to understand how specific forms of human induced land transformation affect the dynamics of Earth's biological systems. Scientists in the Biospheric Sciences Branch are working with conservation biologists from the World Wildlife Fund in a study using daytime and nighttime Earth observation data to quantify the impact of various forms of land use on biological biodiversity. This study is unique in two ways; 1) diurnal (day and night) satellite data are used, and 2) a carbon cycle approach was taken in the assessment of impact. The carbon-based approach focuses specifically on how the conversion of land to urban and other uses affects the net primary productivity (NPP) of the landscape. NPP is the amount of plant material added to the biosphere through photosynthesis and is measured in units of carbon (g C). NPP not only represents a specific amount of carbon removed from the atmosphere, it is also the primary source of food for Earth’s food web supporting all heterotrophic organisms (organisms that require preformed organic compounds for food energy) including human beings.

Nighttime images of the Earth collected by the Defense Meteorological Satellite Program’s Operational Linescan System (DMSP/OLS) showing a dramatic view of city lights were used to delineate urbanized areas across the globe. AVHRR data, collected during daylight hours, were used to examine the comparative health of vegetation within and around urbanized areas (Figure 5). The satellite data were then merged with an extensive biodiversity database of 76 ecoregions in the US with information on thousands of important species. Analyses were carried out focusing on: 1) the consequences of urbanization on NPP in the United States, and 2) the extent to which both urban and agricultural land use types are impinging on biologically diverse ecoregions.

Our results show that urbanization is taking place on the most fertile lands and hence has a disproportionately large overall negative impact on NPP. Urban land transformation in the US has reduced the annual NPP by 0.04 Pg C or 1.6% of its pre-urban value. The reduction is enough to offset the 1.8% gain made by the conversion of land to agricultural use, even though urbanization covers an area less than 3% of the land surface in the US and agricultural lands approach 29% of the total land area. At local and regional scales, urbanization increases NPP in resource-limited regions, and through localized warming "urban heat" contributes to the extension of the growing season in cold regions (Figure 6). In terms of biologically available energy, the loss of NPP due to urbanization of agricultural lands alone is equivalent to the caloric need of 16.5 million people annually, or about 6% of the US population (Figure 7).

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b.

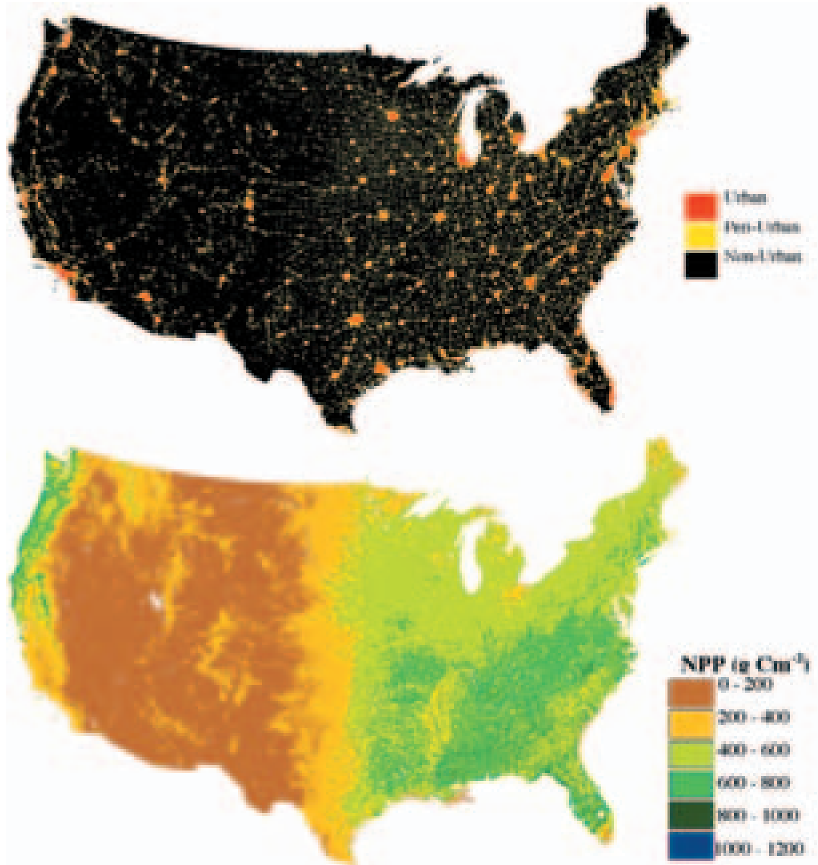
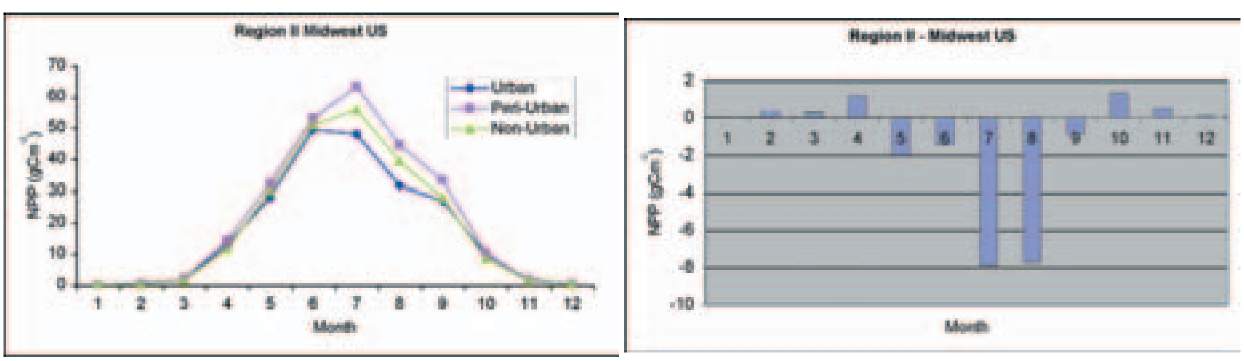


Figure 5. (a) Urbanization map generated from nighttime satellite images from the Defense Meteorological Satellite's Operational Linescan System (DMSP/OLS) collected from October 1994 to March 1995. Red (urban), Yellow (peri-urban), Black (non-urban). (b) Simulated total annual NPP for the U.S. at 1 km x 1 km horizontal resolution.



a.

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Figure 6. Seasonal dynamics of the impact of urbanization on NPP for the Midwestern US. (a) Monthly mean NPP rates for urban (circles), peri-urban (squares), and non-urban (triangles) areas, (b) NPP difference showing the loss (negative) or gain (positive) in NPP rates (gm-2) resulting from urbanization (urban – non-urban). The growing season is extended due to urban heating but productivity is reduced overall compared to non-urbanized areas.

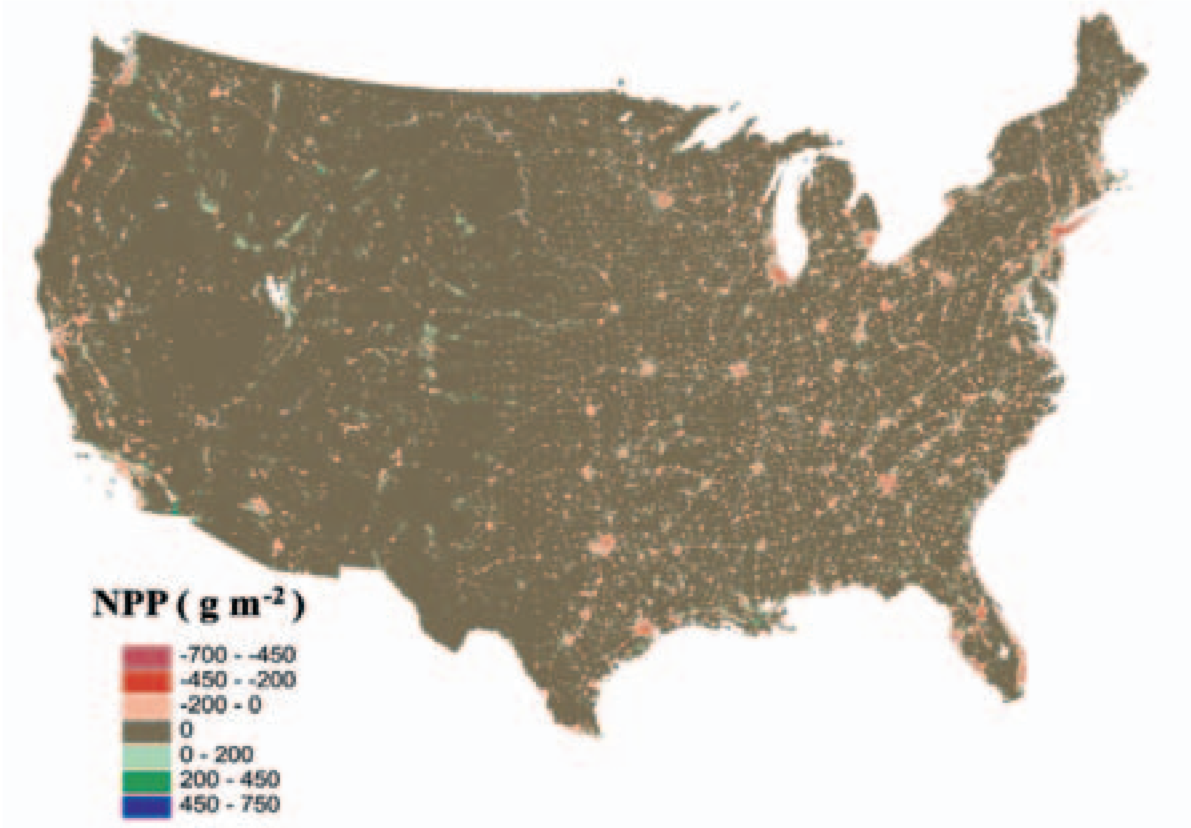

Figure 7. Difference in NPP showing the total annual reduction (negative) or gain (positive) in the rates of NPP(gm-2) (POST-urban – PRE-urban). The overall loss of NPP due to urbanization is 0.04 Pg C annually (about 1.6% of the total annual pre-urban NPP of the continental US) enough to offset the gains in NPP realized by agriculture.

As part of this study we also combined our remotely-sensed measures of urbanization and agriculture with distributional data for eight major plant and animal taxa (comprising over 20,000 species) to assess conservation priorities among 76 terrestrial ecoregions in North America. We combined the species data into overall indices of richness and endemism and compared these indices against the percent cover of urbanization and agriculture in each ecoregion. The analyses yielded four "priority sets" of 6-16 ecoregions where high levels of biodiversity and human land use coincide. The most threatened ecoregions tend to be concentrated in the southeastern U.S., California, and, to a lesser extent, the Atlantic coast, southern Texas and the U.S. Midwest. Across all 76 ecoregions, urbanization is positively correlated to both species richness and endemism, emphasizing that human activities and biodiversity are on a collision course (Figure 8). These results indicate that conservation efforts in densely-populated areas are especially important and perhaps even more important than preserving remote parks in relatively pristine regions for safeguarding biological diversity on the North American continent.

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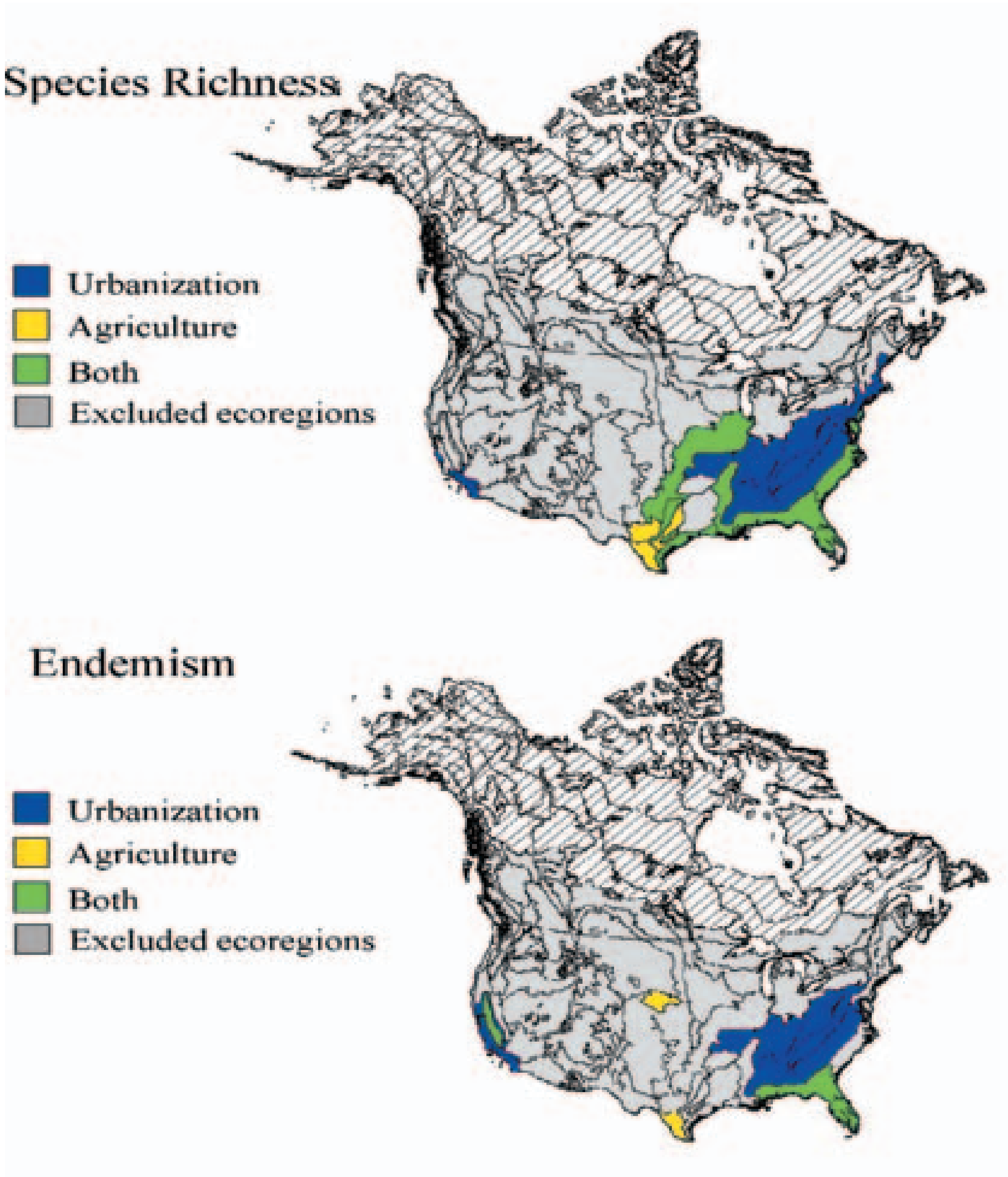

Figure 8. Maps of ecoregions in the top 66% quantile of biodiversity and land use indices. a) richness index versus urbanization, agriculture, or both. b) endemism index versus urbanization, agriculture, or both.

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Forest Characterization

Forests cover approximately 30% of the Earth's land surface and are important to global energy, water and carbon cycles. In addition they provide habitat for animals, protection of soil resources and food and fiber for humans. The alteration of the forest landscape by natural and human factors results in changes in landcover, land use and forest ecosystems. It is imperative for scientists to know the location, amount and type of forests along with structure and productivity and to be able to track the changes in these attributes. Biospheric Sciences forest research covers tropical, temperate and boreal biomes and is multiscaled: from large area characterization of forests and forest change to local scale assessment of forest attributes such as biomass and leaf area. It is a goal of the Laboratory to develop and exploit new technologies that improve the ability to measure forests from space. (References to papers in this Forest Characterization subsection are given at the end of the subsection or, if published in 2002 by Laboratory staff, at the end of the Biospheric Sciences section)

Siberian Forest Cover and Disturbance

Siberian forests are an important source/sink of carbon with total carbon storage in Western Siberia estimated to be 4300 MT, and in Eastern Siberia about 12500 MT. Wildfire is the most important disturbance affecting Siberian forests. Insect invasions, logging, air pollution, and exploitation of mineral reserves are also present in significant amounts. Recent observations suggest that the taiga forests are expanding into the tundra, dark needle conifer (i.e., Siberian pine, spruce, fir) are appearing in larch dominated communities, and post-disturbance succession patterns are changing – all possible indicators of climate warming. Ground studies and remote sensing analysis are being conducted to develop techniques to identify and quantify these changes. Our recent efforts have reported on the use of coarse resolution satellite data (i.e., AVHRR) for forest characterization in central Siberia (Kharuk et al, 2003b) and have made progress toward using higher resolution optical and microwave satellite data for disturbance mapping (Ranson, et al, 2002a, 2003, Kharuk et al., 2002, 2003a). Radar backscatter modeling was used to develop a technique to compensate for the effect of terrain slopes on biomass estimation from SAR data (Sun et al. 2002a). Current work emphasizes on-ground measurements with data fusion to monitor impacts of forest disturbances using temporal and multisource satellite data (e.g., MODIS, MISR, Landsat and SAR).

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Forest Dynamics in Northeastern China

Some 30% of China's forest resources are concentrated in the northeastern provinces of Liaoning, Jilin and Heilongjiang, and the northeastern part of the Inner Mongolia Autonomous Region. This area has seen tremendous change during the 20th century, ranging from widespread clearing for agriculture and timber in the early part of the century, to ambitious reforestation programs beginning in the 1970's. Terra MODIS and Landsat are being used to map the current extent of forests in Northeastern China, track the changes in forest cover during the 1990's, and initiate a GIS-based monitoring system to provide updated forest cover maps in the future. To date, new forest cover maps have been made from multi-temporal classification of MODIS NDVI data (Sun et al., 2002c). These maps agree with aggregate statistics provided by the Chinese Academy of Forestry. Landsat imagery from 1990 and 2000 were used to estimate rates of forest clearing and re-growth (Sun et al. 2002b). The results suggest that during the decade of the 1990's forest cover in Northeastern China remained roughly stable, possibly increasing by about 0.2% per year. Significant deforestation has occurred locally, however, as a result of agricultural conversion within foothills along the perimeter of the Manchurian plain.

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Siberian Forest Leaf Area Index

The goal of the Leaf Area Index for Fire Chronosequences in Siberian Boreal Forests study is to determine leaf area index (LAI) for four different post-fire age sites using both surface and remotely sensed data. There is a lack of data for this area of the world, and good information is needed for accurate global assessment of carbon storage potential. Field campaigns to collect surface data were conducted in 1999, 2000, and 2001, and Landsat, MODIS, and IKONOS imagery have been acquired. The past year was spent assembling, analyzing, and preparing the data for publication. LAI values for the sites roughly follow theoretical predictions. Total (and overstory) LAI values for each of the post-fire stand ages are as follows (LAI in units of m^2/m^2): 0-2 year site: 0.2-0.4 (0.0); 13 year: 1.4-3.0 (0-2.4); 25 year: 1.0-4.0 (0.8-2.8); and over 100 years: 5.5-9.1 (4.3-8.7). Variations occur due to heterogeneity across the site in both fire severity and vegetation regrowth patterns. Relationships between surface data and vegetation indices developed from satellite data are not strong which is hindering extrapolation of site values to broader scales. This work will continue in 2003.

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Tropical Forest Structure with Lidar

There were two important milestones in the efforts to develop global measurements of vegetation biomass from lidar published in 2002. The quality of lidar-derived estimates of aboveground biomass from La Selva Biological Station, based on data collected in 1998 using a Laboratory developed instrument, LVIS, have set a new standard for biomass remote sensing in tropical forests (Drake et al., 2002a). Simple functions of lidar waveforms explained more than 90% of the variation in field biomass data (89% in cross-validation tests). Also performed was a basic validation of vertical distributions of intercepted surfaces from lidar, showing that differences between distributions in lidar waveforms and those reconstructed from simple tree crown geometry were smaller than those characterizing land-cover type differences (e.g., primary versus secondary tropical forest) within the same data source (Drake et al., 2002b). Together with results from the temperate zone, and work in review reporting good results estimating biomass from lidar in semi-deciduous tropical forest, these findings confirm that lidar can be a vital tool for research on the global carbon budget. No other remote sensing method does as well at resolving biomass differences among very tall, dense forests.

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Delaware Forests Inventory Using an Airborne Laser

Forest inventory estimates of volume and biomass and acreage estimates of various forest height-canopy cover classes were generated from a single set of airborne laser profiling data acquired during the summer of 2000. The stratum, county and statewide estimates of above-ground dry biomass may be converted directly to estimates of standing carbon. A portable, inexpensive lidar called PALS (Profiling Airborne Lidar Sensor) was used to inventory forests statewide; in addition, the systematic laser measurements were used to identify and map mature forest stands which might support the Delmarva Fox Squirrel (Sciurus niger cinereus), an endangered species previously endemic on the Eastern Shore of the Chesapeake Bay. Merchantable volume estimates were within 14% of US Forest Service estimates at the county level and within 4% statewide. Total above-ground dry biomass estimates were within 19% of USFS estimates at the county level and within 16% statewide. The laser heights and the biomass estimates derived from those measurements demonstrate the utility of an airborne laser for forest characterization and mensuration. See Figure 9.

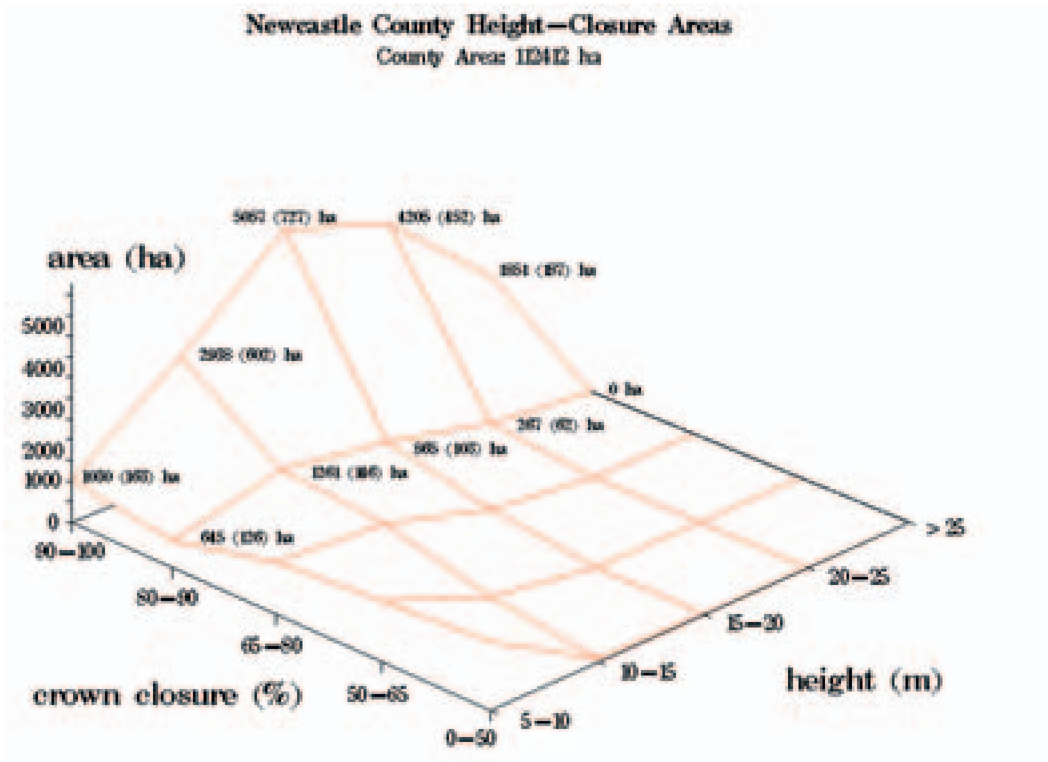

Figure 9. 3-D surface of forest height - crown cover classes in Newcastle County, Delaware. The numbers in parentheses are the associated standard errors of estimate.

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Verification and Evaluation of SRTM Data

Efforts continued towards validating Shuttle Radar Topography Mission (SRTM) digital elevation models (DEMs). SRTM is expected to improve on existing DTED-1 DEMs (Figure 10). SRTM data has lower vertical accuracy but higher horizontal resolution and accuracy than satellite lidar data (such as Shuttle Laser Altimeter (SLA) and the recently launched Geosciences Laser Altimeter System (GLAS)), and the vertical accuracy of the SRTM data is less affected by the local slope. Cross-verification of surface height from these instruments is critical for technique advancement and applications. Field work in Russia was conducted in August 2002 by U.S. and Russian investigators. The forests near or within SLA-02 footprints were sampled for tree diameter at breast height (dbh), height and stem density along with GPS location. It was found that the land cover types and forest structures match the SLA-02 waveforms. The surface height profiles measured by SLA-02 and SRTM are highly correlated (R2 > 0.95). The surface height discrepancies between SRTM and SLA-02 are random at open areas and are correlated to tree heights (for details see Sun et al 2002d). SRTM provides improved elevation data, which will be essential for co-registration of satellite images from different platforms, and reduction of terrain effects on SAR (synthetic aperture radar) data. Figure 10 shows SRTM Digital elevation data for a portion of central Siberia. Further studies will be conducted when the GLAS data becomes available.

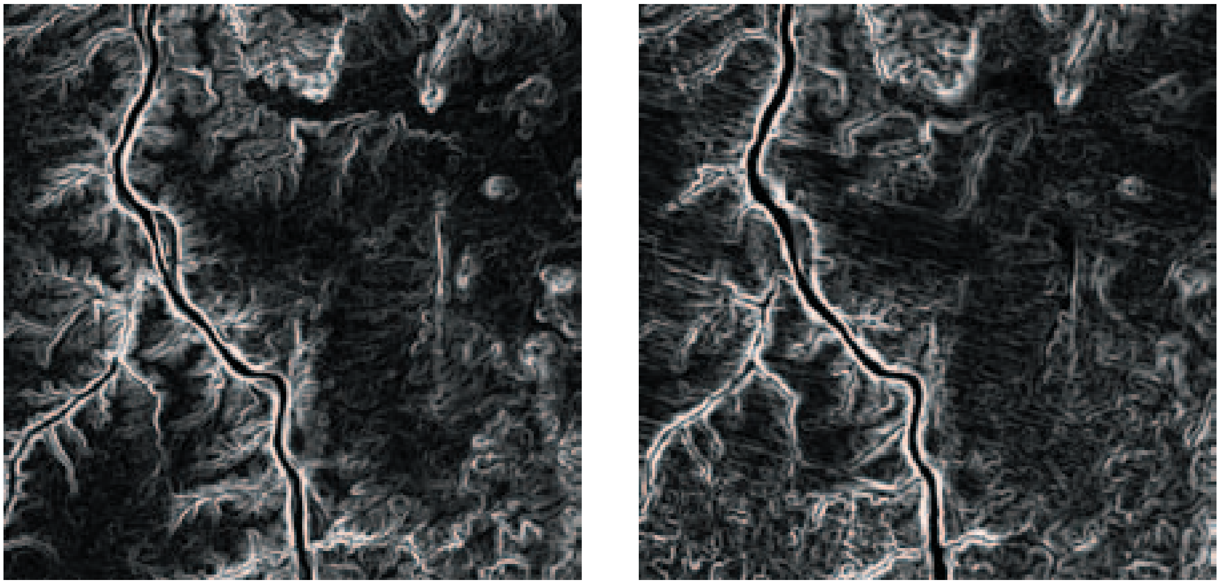

Figure 10. Local slope calculated from SRTM DEM (left) and DTED-1 DEM (right) of the Yenisei River Valley in Central Siberia. Note the greater detail in drainage basin topography of the SRTM DEM, and the noisy stripes from the DTED-1 data.

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BRDF Model Inversion Using Neural Networks

Radiative transfer models for forest canopies serve as a basis for extracting forest characteristics using directional/spectral data from satellite sensors (e.g. MODIS, MISR, POLDER, SeaWiFS). Only recently have there been significant efforts made to provide operational algorithms to invert these models. These efforts have exposed a need to significantly improve the efficiency and accuracy of traditional efforts for inverting these physically based models. In an effort to overcome the limitations of traditional inversion methods, a neural network method was designed and tested. Neural networks provide a computational structure which allows it to learn complex nonlinear relationships that cannot be envisioned by a researcher. In this study a complex 3D model (Discrete Anisotropic Radiative Transfer, DART) developed by Dr. J. Gastellu-Etchegorry and others from CESBIO, France, was inverted using POLDER-like data. The model was inverted to recover forest characteristics such as forest cover, leaf area index, and soil reflectance. The neural network method was significantly more accurate than the traditional methods. By using only a few directional view angles as opposed to only a nadir view the accuracy of recovering forest canopy characteristics was significantly improved (Kimes, et al, 2002). This neural network approach can provide an accurate, efficient, and stable inversion method for radiative transfer models using directional/spectral data from satellite-borne sensors.

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Radar-Lidar Fusion

Derivation of forest structure is vital for understanding forest state and change and the implications of the carbon cycle information retrieval from lidar and radar data. Radar backscatter and lidar waveform models, which are based upon a common three-dimensional forest stand structure, were parameterized using realistic forest physical stands to produce a data set of forest structural parameters and lidar/radar responses. Both radar backscatter and lidar waveform models are three-dimensional, and were parameterized using forest attributes simulated from a forest succession model, ZELIG, developed at the University of Virginia. The radar backscattering and lidar waveforms were calculated for a number of stands. This approach allows comparison of radar and lidar interaction with forest canopies and is useful for investigating the data characteristics of these active sensors and the relationships between these new data (Sun and Ranson 2002). Further studies on the definition and retrieval of potential parameters or indices from lidar waveforms will be done, so the commonality and complementarily of lidar and radar data can be better understood, and the critical structural variables driving the signature be identified.

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Southern Africa Burned Area Mapping

Southern Africa is subjected to some of the most extensive biomass burning in the world. Fires occur due to both natural and anthropogenic causes, primarily lightening and land management. Information on the timing and spatial extent of fire is required to allow managers, planners, and policy makers the opportunity to understand fires in their environmental, economic, and social contexts and to formulate their responses accordingly. At regional to global scales this information is required to estimate trace gas and particulate emissions associated with natural and anthropogenic fires, important for understanding loss of biomass and release of carbon and greenhouse gases to the atmosphere and their associated radiative forcing on the climate.

Satellite remote sensing provides the only practical means to monitor biomass burning over areas as extensive as southern Africa. Active fire locations have been derived systematically by hotspot detection algorithms applied to orbital satellite data. However, these data do not provide reliable information on the spatial extent and timing of burning as clouds preclude hotspot detection and because the satellite may not overpass when burning occurs. Algorithms that use multi-temporal satellite data to map the areas affected by the passage of fire, often called burned areas, are less subject to these constraints. A new approach to change detection, applicable to high-temporal frequency satellite data, that maps the location and approximate day of change occurrence, has been developed. The algorithm has been used to generate southern Africa burned area maps for 2000 – 2002 from daily MODIS 500m land surface reflectance data.

Figure 11 illustrates the 500m MODIS burned area product (colored pixels) and validation data (vectors) over the Okavango delta, Botswana, in the 2001 dry season. The correspondence between these independently derived burned area data sets and the coherent spatio-temporal progression of burning is evident. The validation data were derived from multi-temporal Landsat Enhanced Thematic Mapper Plus (ETM+) data following a protocol implemented by members of the Southern Africa Fire Network (SAFNet) in Namibia, Botswana, Zimbabwe, Malawi, South Africa, and Mozambique. The MODIS burned area product is now being considered for global implementation and to feed SAFNet local and regional resource management and environmental assessment applications in addition to regional greenhouse gas emission inventories.

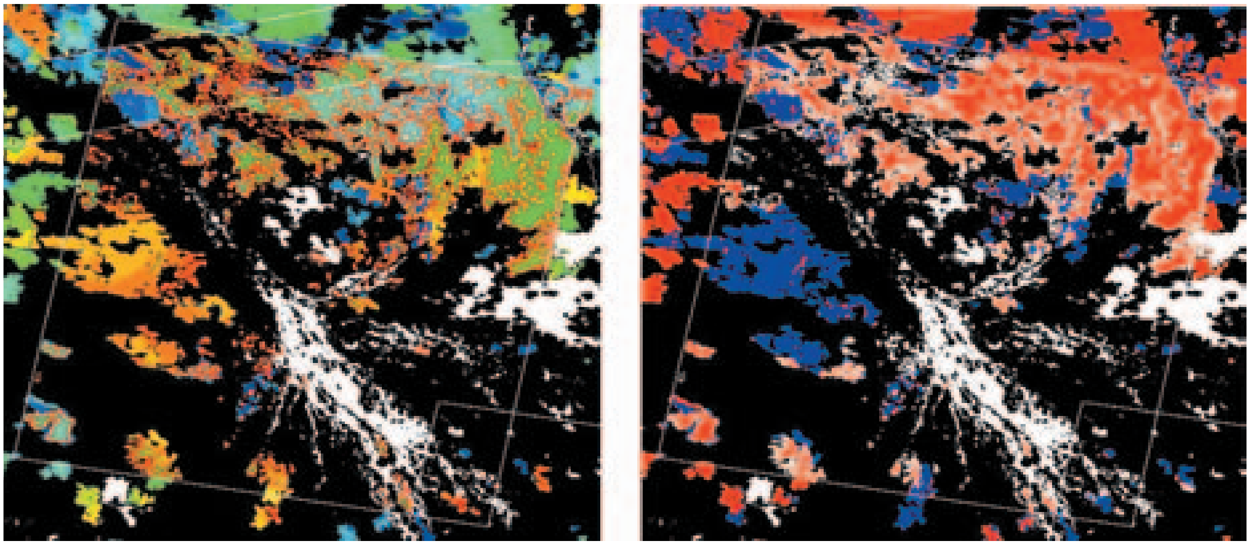

Figure 11. MODIS 500m burned area product and Landsat ETM+ independent burned area validation data, Okavango delta, Botswana. Vectors show independent burned area data mapped in the period between two ETM+ acquisitions 6 August and 23 September 2001 (left- red vectors, right- white vectors). Colored pixels show the burned areas detected by MODIS over 105 days from 20 July to 1 November 2001 (left- colored with a rainbow scale to indicate the approximate day of burning, bottom- right to indicate burned areas detected within the Landsat ETM+ acquisition period, blue to indicate MODIS burned areas detected before or after the ETM+ acquisition period). Black pixels indicate no burning detected by MODIS, white pixels indicate areas that could not be mapped due to persistent cloud. The 185 X 170 km Landsat ETM+ scene boundary and the borders of Botswana, Namibia (Caprivi Strip) and Angola are also shown (white vectors, top and bottom).

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References for Forest Characterization:

Kharuk V. I., Ranson K. J., Kuz'michev V. V., Im S. T. 2003a. Landsat based analysis of insect outbreaks in southern Siberia, In Press, Canadian J. Remote Sensing

Kharuk V.I., Ranson K.J., Burenina T.A., Fedotova E.V.2003b. NOAA/AVHRR data in mapping of Siberian forest landscapes along the Yenisey transect, International J. Remote Sensing, in press.

Nelson, R.F., G. Parker, and M. Hom. 2003. A Portable Airborne Laser System for Forest Inventory. Photogrammetric Engineering and Remote Sensing, accepted for publication.

Nelson, R.F., A. Short, M. Valenti, and C. Keller. 2003. A Multiple Resource Inventory of Delaware Using Airborne Laser Data. submitted to BioScience.

Ranson, K. J., K. Kovacs G. Sun, V. I. Kharuk. 2003. Disturbance recognition in the boreal forest using radar and Landsat 7, In press, Canadian J. Remote Sensing

Health Initiatives

Pediatric Asthma Study

The problem of pediatric asthma in Baltimore, Maryland is serving as a prototype for the development of tools that would contribute to decision support systems being used within the medical and public health communities. An epidemic of pediatric asthma is underway in the US in that the number of children with asthma has more than doubled in the last 15 years. National data also show that poor, minority children are disproportionately affected, requiring higher rates of hospitalization for asthma and incurring higher mortality rates. In Baltimore City, asthma is the most common chronic illness of children accounting for up to 20% of pediatric hospital admissions, with rates more than double the national rate.

Temporal and spatial trends in hospital admissions and emergency room visits within Baltimore show some relationship to environmental and socioeconomic trends. However, the number of possible variables involved and the complex, non-linear relationships between these variables makes it extremely difficult to understand. In order to handle the large and diverse data sets to identify environmental causes of childhood asthma, the following tools have been developed: data collection, data integration with GIS, data manipulation, visualization and scenario building, and applied mathematical modeling and prediction.

Accomplishments to date include

1. The development of a robust tool for data integration and manipulation which includes:

- Input of multidisciplinary data
- Encapsulation of complex and diverse data sets into a common format
- Conversion between spatial and temporal units (e.g. census to zip code)
- Spatial and temporal integration of inputted data in a GIS structure
- Graphical user interface for easy access to data and tools
- Clipping tool for choosing locations or areas for graphical or digital output
- Graphical output including thematic maps (State, county, zip code, census tract, and others), multiple graphing for displaying data
- Prediction capabilities using adaptive non-linear techniques (e.g. neural networks)
- Output of integrated data sets based on overlaying spatial or temporal criteria
- Data manipulation (e.g. weighting, adding, subtracting, multiplication, division, etc.) for query and decision making

2. Collection of a comprehensive set of environmental, clinical, and socioeconomic data including:

- Clinical data
- Socio-Economic data
- School data
- Weather Air Quality
- Water Quality
- Environmental (pollen, molds, brownfields, soil properties, topography, etc.)
- Land Use and Boundaries (roads, cities, traffic, major industrial areas, agricultural etc.)
- Remote Sensing (Landsat, AVHRR, Ikonos, SPOT, Aeronet, MODIS, ASTER, etc.)

3. Production of remote sensing products including:

- Land cover classification and land use change (for vegetation type, amount, cropland, and urban extent) from Landsat

- Urban characteristics for Baltimore City (Landsat)
- Animation of timing of greenness (SPOT, 1KM, 1998-2002) (for relating vegetation phenology, and agricultural activity to asthma trends)
- Pollution maps derived from Landsat (NO_2, SO_2,CO) (in development)
- Key landmark features overlaid on 1m IKONOS base map
- Particulate matter load, size, and characterization from Aeronet

4. Preliminary Research Results:

- Asthma rates are high in Baltimore City, Maryland, compared with national rates, with 5-14 year olds disproportionately affected.
- There is a strong seasonal pattern in pediatric asthma hospital admissions in Baltimore City with peaks in spring and fall and lows in summer and winter.
- The same seasonal pattern and timing of peak admissions is observed throughout the State of Maryland.
- This seasonal pattern supports relationships between asthma and certain classes of environmental triggers and contradicts relationships previously linked with asthma (e.g. high atmospheric ozone).
- Predictions of temporal asthma hospital admissions in Baltimore City can be made with relatively high accuracy based solely on historical trends (r^2 = .80).
- Highly accurate spatial predictions of asthma hospital admissions were made in Baltimore City using satellite based information (Landsat) combined with socio-economic data (r^2 = .95). The characteristics of zip codes areas with high pediatric asthma hospitalization rates were:
    - Highest proportion of families headed by single parent
    - Highest levels of poverty
    - Highest proportion of built-up areas
    - Lowest vegetation cover
    - Highest thermal IR radiant temperatures
- Schools with the highest prevalence of asthma were identified (based on data from school nurses) and chosen for further study of indoor triggers. Results showed that allergens found indoors within the Baltimore City Public schools do not appear to be high enough to be the primary trigger of pediatric asthma in Baltimore City.

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Satellite Remote Sensing of Ebola River Hemorrhagic Fever Outbreaks

Ebola hemorrhagic fever, named after the Ebola River in equatorial Africa, first appeared in June 1976, during an outbreak of 284 cases in Nzara and Maridi, Southern Sudan with a fatality rate of 53%. In September 1976, another outbreak of 318 cases occurred in Yambuku, Democratic Republic of the Congo (DRC), in which 88% of the affected died. One fatal case was identified in Tandala, DRC, in June 1977, followed by an outbreak involving 34 cases with 20 deaths, again in Nzara, Sudan, in July 1979 (a residual outbreak).

Ebola River hemorrhagic fever was not reported again until the end of 1994, when three outbreaks occurred within a relatively short time. In October, an outbreak was identified in a chimpanzee group in Tai, Cote d'Ivoire (12 chimpanzee cases, all chimps died) with one human infection that was not fatal. Forty-nine cases (59% fatal) were reported the following month in northeast Gabon in the gold panning camps of Mekouka, Andock, and Minkebe. Later that same month, 315 cases (77% were fatal) were reported at Kikwit, DRC, through unknown initial exposure thought to have occurred to men working in a charcoal pit. In Gabon, two subsequent outbreaks were reported in February and July 1996, respectively, in Mayibout II, a village 40 km south of the original outbreak in the gold panning camps (31 cases, 68% of whom died), and a logging camp between Ovan and Koumameyong, near Booue (60 cases and 40 deaths); these cases are thought to be residuals from the initial Gabon November 1994 outbreaks.

The emergence of Ebola hemorrhagic fever in equatorial Africa is enigmatic. It is thought to result from, or to be facilitated by, human intrusion into previously uninhabited tropical areas, changes in the ecology of the Ebola virus or its natural reservoir(s), mutation of the Ebola virus, and possibly severe climatic conditions, which could serve as a "trigger" event. No reservoir or vector has yet been found. The work is described in more detail in Tucker et al. (2002).

All known outbreaks of Ebola have been linked to tropical forests. A study of environmental conditions associated with Ebola hemorrhagic fever was conducted after preliminary reports strongly suggested that simultaneous outbreaks occurred, during two limited time periods in the 1970s and 1990s, immediately following a sudden shift from a very dry to a wet period. The study investigated climatic conditions associated with the documented outbreaks and the degree of human intrusion in the outbreak areas using satellite data in the 1981 to 2000 time period. No time-series satellite data are available for the 1970s; thus the satellite time series analysis is restricted to outbreaks in the 1990s. Work is continuing to extend the analysis from 2000 through to early 2003.

Ebola hemorrhagic fever outbreaks were identified from documented, clinically described, and serologically confirmed cases. The date of the first documented Ebola case was used to define the start of each outbreak. The assumption was made that the first or index case had come into contact with Ebola virus up to 25 days prior to the onset of the illness. This includes an incubation period of 21 days plus additional time spent between onset of symptoms and subsequent appearance at a clinic.

Landsat multispectral scanner [MSS] (80 m spatial resolution) and thematic mapper [TM] (30 m spatial resolution) data were acquired for the outbreak times and locations to determine the ecological setting. The respective vegetation associations ranged from primary tropical forest in a continuum of tropical forest (Gabon and Zaire sites), isolated primary tropical forest surrounded by human activities (Cote d'Ivoire site), or gallery tropical forest in a savanna matrix (Sudan sites).

Data from the Advanced Very High Resolution Radiometer (AVHRR) instrument carried on board the National Oceanic and Atmospheric Administration's (NOAA) polar orbiting series of satellites was used to create monthly normalized difference vegetation index (NDVI) mapped to 8 km resolution grid for all of Africa. NDVI is used as a surrogate for photosynthetic capacity, which is directly influenced by rainfall. The NDVI is computed from the red (550-700 nm) and near infrared (730-1100 nm) channels of the AVHRR according to:

$$\text{(1)} \qquad NDVI = (r_{nir} - r_r) / (r_{nir} + r_r)$$

where r_{nir} and r_r are the surface reflectances in the 730-1000 nm and 550-700 nm regions of the electromagnetic spectrum, respectively.

Maximum value compositing was performed to minimize the effects of cloud contamination, atmospheric effects, scan angle and solar zenith angle effects without having to resort to an explicit atmospheric correction. A time and latitude varying atmospheric correction was applied for the El Chichon (1982-1984) and Mt. Pinatubo (1991-1993) stratospheric aerosol periods. Data were inter-calibrated between different satellites periods and corrected for sensor degradation. Nearly two decades of data were processed from four NOAA satellites, NOAA-7 (1981-1985), NOAA-9 (1985-1988), NOAA-11 (1988-1994), NOAA-9 (1994-1995, descending node 0900 hour local solar overpass time), and NOAA-14 (1995-1999). The composite images were visually checked for navigation accuracy, tested for spatial coherence and then assembled into time series.

Monthly mean NDVI images were derived from the time series by computing the respective 18 year mean images, taking care not to include outlier or missing data values in the mean. Monthly NDVI anomaly images were then computed by taking the difference between the monthly NDVI and that of the respective monthly mean.

The NDVI anomaly images were then analyzed to reveal spatial patterns and temporal persistence of above normal and below normal NDVI. NDVI time series profiles of anomalies were developed for outbreak locations in Tai, Cote d'Ivoire; Mekouka, Gabon; and Kikwit, DRC.

A threshold algorithm was applied to the NDVI time series to identify regions in the tropical forest stratum experiencing a change from persistently below-normal NDVI to persistently above-normal NDVI conditions. A tropical forest stratum mask was constructed based on NDVI values between 0.4 and 0.8 in the computed 18-year annual mean NDVI image. Geographic areas associated with major negative-to-positive NDVI anomaly changes were calculated using criteria of anomaly severity, persistence, and clustering: (1) two months of persistent negative ΔNDVI < -0.025 followed by one month ΔNDVI >0.025; (2) three months of persistent negative ΔNDVI < -0.025 followed by two months Δ NDVI >0.025 and only selecting pixels surrounded by similarly-affected pixels; (3) three months of persistent negative ΔNDVI < -0.05 followed by two months ΔNDVI >0.05 with no test for similarly-affected pixels; and (4) three months of persistent negative ΔNDVI < -0.05 followed by two months ΔNDVI >0.05 and only selecting pixels surrounded by similarly-affected pixels (Figure 12). Distances from the nearest group of anomaly pixels were then calculated for each of the documented outbreak sites.

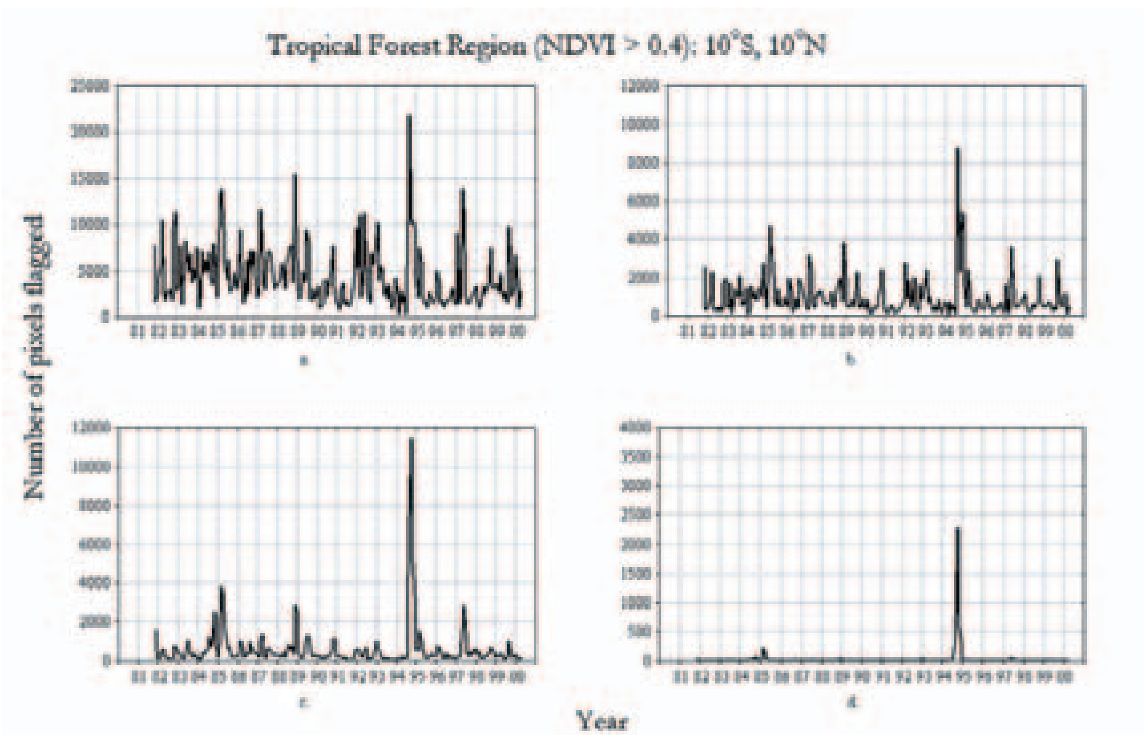

Figure 12. Using the NDVI profiles, the number of pixels in the tropical forest stratum of Africa were computed where possible NDVI "trigger" events occurred. These were summed and plotted vs. time. (a) a ΔNDVI of 0.025 with 2 months <0.025 followed by 1 month > 0.025; (b) a ΔNDVI of 0.025 with 3 months <0.025 followed by 2 months > 0.025; (c) a ΔNDVI of 0.05 with 3 months <0.05 followed by 2 months > 0.05 without any pixels "filtered"; and (d) a ΔNDVI of 0.05 with 3 months <0.05 followed by 2 months > 0.05 where only those pixels surrounded by similar flagged pixels are included.

Analysis of time series profiles of NDVI anomalies developed for the 1994-1996 outbreak locations showed a common feature for all three locations (Tai, Mekouka, and Kikwit): a significant change from below average NDVI values to above average NDVI within a short period of time. The relative change was on the order of 0.2-0.3 NDVI units within a four-month period.

Large areas of marked NDVI changes existed for the Gabon and Congo 1994 Ebola outbreak areas. These marked NDVI changes preceded the 1994 outbreaks by 1 to 4 months and occurred within 60 km from the documented outbreak locations. The situation for Tai, Ivory Coast does not follow this pattern and indicates an Ebola antecedent outbreak >200 km distant. Because local rainfall data reported very high precipitation at this location in October 1994, it is unclear if the remote sensing analysis is too conservative for the Tai outbreak or if introduction of the virus occurred with a highly mobile species.

Distances of up to 220 km would need to be traversed if the Ebola virus outbreak at Tai, Ivory Coast was associated with the rainfall and hence NDVI anomaly which we mapped for tropical Africa. The 60 km distances found for the 1994 Gabon and Congo Ebola outbreak sites are plausible for a combination of arthropod, vertebrate, and/or "infected person" transmission, ultimately to people in the documented outbreak areas.

This analysis is limited by the occurrence of only one Ebola outbreak during our 1981-1999 satellite record. Work is continuing to complement the NDVI time series with a companion time series of satellite-derived surface temperature and the addition of NDVI data for 2000-2001. Recent advances in satellite remote sensing will also provide retrievals of near-surface humidity and precipitation, in addition to improved normalized difference vegetation index time series which is being continued by several different instruments flying on several different satellites.

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Field and Airborne Research Experiments

<u>The Vegetation Fluorescence Project</u>

The Vegetation Fluorescence Project is a joint NASA and USDA project conducted at the Agricultural Research Service in Beltsville, MD. The major focus of this project is to understand the interaction of the nitrogen (N) and carbon (C) cycles affecting plant productivity. This interaction was researched through optical, physiological, and morphological measurements related to C and N uptake and photosynthetic function of vegetation included in controlled N application experiments. Three essential state-of-the art instruments to augment the measurement capabilities of this study were used: a spectrofluorometer (Fluorolog-3); a leaf chamber capable of simultaneously obtaining chlorophyll fluorescence and photosynthesis; and a solar simulator.

In 2001, this project focused on laboratory measurements of field grown corn that were provided four levels of nitrogen fertilizer application. Preliminary results from the 2000 and 2001 growing seasons were presented in four IGARSS'02 papers (Toronto, Canada, June 23-27, 2002); a SPIE paper (9th International Symposia on Remote Sensing, Crete, Greece, September 22-27, 2002); a paper presented at a workshop entitled "Remote Sensing for Agriculture and the Environment" sponsored by the Organization for Economic Cooperation and Development (OECD) in Kifissia, Greece (Sept 17-20, 2002); a poster included in the 2002 BARC Poster Day (April 18, 2002); and a poster/presentation (Oct. 3, 2002) for the USDA Deputy Under-Secretary for Research, Education and Economics, Dr. Rodney Brown. Results from these years were also included in a journal paper submitted to Remote Sensing of Environment (Corp et al.).

Due to the 2002 drought, additional data on field corn was not acquired this year. Instead, a controlled N experiment was undertaken, which is expected to continue for three years. Funded by the NASA Terrestrial Ecology Program, the study researches the effects of excess N that might occur in riparian forests due to either pollution inputs from the atmosphere or land runoff, for seedlings of three tree species (red maple, sweet gum, tulip poplar). Beginning in early June, N was applied bi-weekly at four dose levels. Week-long measurements campaigns were conducted at three different times during the growing season (mid July, early September, early October) on a sample of 60 (out of 200) trees.

Experiments were also conducted in 2002, sponsored by the Defense Threat Reduction Agency (DTRA), on several species (corn, soybean, pigweed) to determine whether fluorescence was altered in the foliage of plants exposed to trinitrotoluene (TNT) in the substrate. Optimal N or TNT was applied in four dose levels weekly to potted plants held in a cold frame with removable covers. Three week-long measurement campaigns were conducted in June, July, and September. Preliminary results of these experiments were presented at a joint NASA/National Institute of Justice meeting held at GSFC in November.

A standard set of measurements made on individual leaves has been established. Spectral measurements acquired from both upper and lower leaf surfaces included: 1) emission images acquired in four bands (blue, green, red, far-red bands, 10-20 nm wide), induced by broadband UV/VIS excitation, with the in-house Fluorescence Imaging System; 2) high spectral (5 nm) fluorescence emission spectra, resulting from single wavelength excitations at 532, 350, and 280 nm, acquired with the Fluorolog-3 spectrofluorometer; 3) high spectral resolution (<3 nm; ~400 - 2500 nm) optical properties (reflectance, transmittance, absorptance) acquired with a spectroradiometer (Analytical Spectral Devices, Inc., ASD) and an integrating sphere; and 4) the percent of "apparent reflectance" in the red edge spectrum (650 - 750 nm) due to chlorophyll fluorescence, calculated from ASD optical spectra acquired at 1 s intervals (for 2 min) with/without a Schott RG 665 long pass filter, after exposure of dark-adapted leaves to simulated solar irradiance. Some measurement sets also included 3-D fluorescence excitation matrices for fixed emission wavelengths (e.g., solar Fraunhofer lines, 677 and 745 nm). Also determined were photosynthetic parameters, chlorophyll fluorescence kinetics, pigment content, N and C content; and specific leaf mass, chlorophyll fluorescence kinetics, and pigment content.

The NASA participants are associated with the Biospheric Sciences Branch: Dr. Elizabeth Middleton , Dr. Petya K. Entcheva Campbell, UMBC/JCET; and SSAI employees, Larry A. Corp, L. Maryn Butcher, Phillip Padden, and Emmett Chappelle (formerly 923). The USDA participant is James E. McMurtrey, III of the Hydrology and Remote Sensing Laboratory at BARC.

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EOS Land Validation Core Sites and CEOS Land Product Validation

Based on lessons learned from the previous generation of global land imaging systems (Justice and Townshend, 1994), NASA considers product validation to be an integral component in the production of global land products. For each product derived from satellite data there needs to be field data, or ground reference, to ensure that the information in the satellite product is accurate. For global products produced in the 250m to 1km spatial resolution range, high-resolution (4 to 30m) airborne or satellite data provide a useful intermediate point from which to relate ground measurements to the course resolution global products. To facilitate validation efforts over a network of field sites, the MODIS land team continues to develop an online infrastructure of data and information for the EOS Land Validation Core Sites, including the systematic collection of remote sensing data from other missions. Using the EOS/MODIS land product validation experience, research at GSFC has led land product validation efforts within the international community. The EOS Core Sites and participation in the CEOS Land Product Validation subgroup are a joint activity between the Terrestrial Information Systems and Biospherics Sciences Branches, within the Laboratory for Terrestrial Physics.

EOS Land Validation Core Site: update

The EOS Land Validation Core Site system was initiated by the MODIS Land Validation Team to coincide with the launch of Terra. One of the primary goals of Goddard and the MODIS Land Team's efforts in support of the EOS Land Validation Core Sites was to provide easy access to EOS data for research sites around the world. Although their development was primarily for the validation of EOS data, the Core Site infrastructure can and has been used for validation of many satellite sensors (Morisette, et al., 2002).

Currently there are 26 Core Sites, with free ftp access available for most of the Core Site data sets. These data include ETM+, ASTER, and 200 x 200 km subsets of MODIS and SeaWiFS data. Many of the Core Sites are already part of existing science data networks, such as the FLUXNET network http://daacl.esd.ornl.gov/FLUXNET/), AERONET (http://aeronet.gsfc.nasa.gov:8080/), and the Long Term Ecological Research site network (LTER: http://www.lternet.edu). High-resolution IKONOS data are also available for the Core Sites (NASA Scientific Data Purchase program registration required). In August 2002, the EOS Land Validation Core Site WWW pages reached the 1000 link milestone, where each link points to a unique satellite data set. The EOS Land Validation Core Site system continues to serve validation of global land products from MODIS Terra and Aqua, as well as other multi-resolution science research at these sites.

CEOS LPV

In an attempt to leverage off of the infrastructure and experience from MODIS Land validation, researchers at GSFC have helped establish the Committee on Earth Observing Satellites (CEOS) "Land Product Validation" (LPV) Subgroup. Since the LPV subgroup's inception in late 2000, Goddard scientists have chaired the subgroup and have also organized several outreach workshops.

The mission of the subgroup is to foster quantitative validation of high-level land products derived from remote sensing data in the solar reflective and thermal infrared wavelengths. It will pursue this mission through the following objectives:

- To define uncertainty objectives with product users

- To identify and support global test sites for both systematic and episodic measurements

- To develop consensus "best practice" protocols for data collection, description, scaling, and comparison with satellite products

- To identify needs and opportunities for coordinating collaboration among space agencies, industry, academia, and scientific organizations and networks.

- To develop procedures for validation, data exchange, and management (with the Working Group on Information System and Services, WGISS)

These objectives are being achieved through a series of topical workshops, international product intercomparison activities, and a transition from the EOS to CEOS Land Validation Core Sites. The topical workshops are co-chaired by community experts, focusing on specific land product validation issues. The initial programmatic focus will be on the Global Observation of Forest and Land Cover Dynamics (GOFC/GOLD) priorities of Fire/Burn Scar products, Land Cover/Land

Cover Change products, and Biophysical products (such as Leaf Area Index, LAI and Albedo). Collaboration with industry, data centers, satellite product developers, and other CEOS working groups and their subgroups, will be sought. The initial LAI workshop has resulted in the "CEOS LAI-Intercomparison Activity", where several separate international efforts are being combined to provide independently-derived high-resolution LAI maps for over 20 sites (see Figure 13). These maps can then be compared to the MODIS (or other) global LAI products, thus providing more validation sites than any one agency alone could develop. To transition from EOS to CEOS Land Validation Core Sites, LPV has led a joint activity between its parent working group (the Working Group on Calibration and Validation) and the other working group of CEOS (the Working Group on Information System and Services). This "Test Facility" will be similar to the EOS Core Site infrastructure but will provide access beyond NASA's EOS satellite data sets, and look to include any global land product that is produced by a CEOS member (see Figure 14).

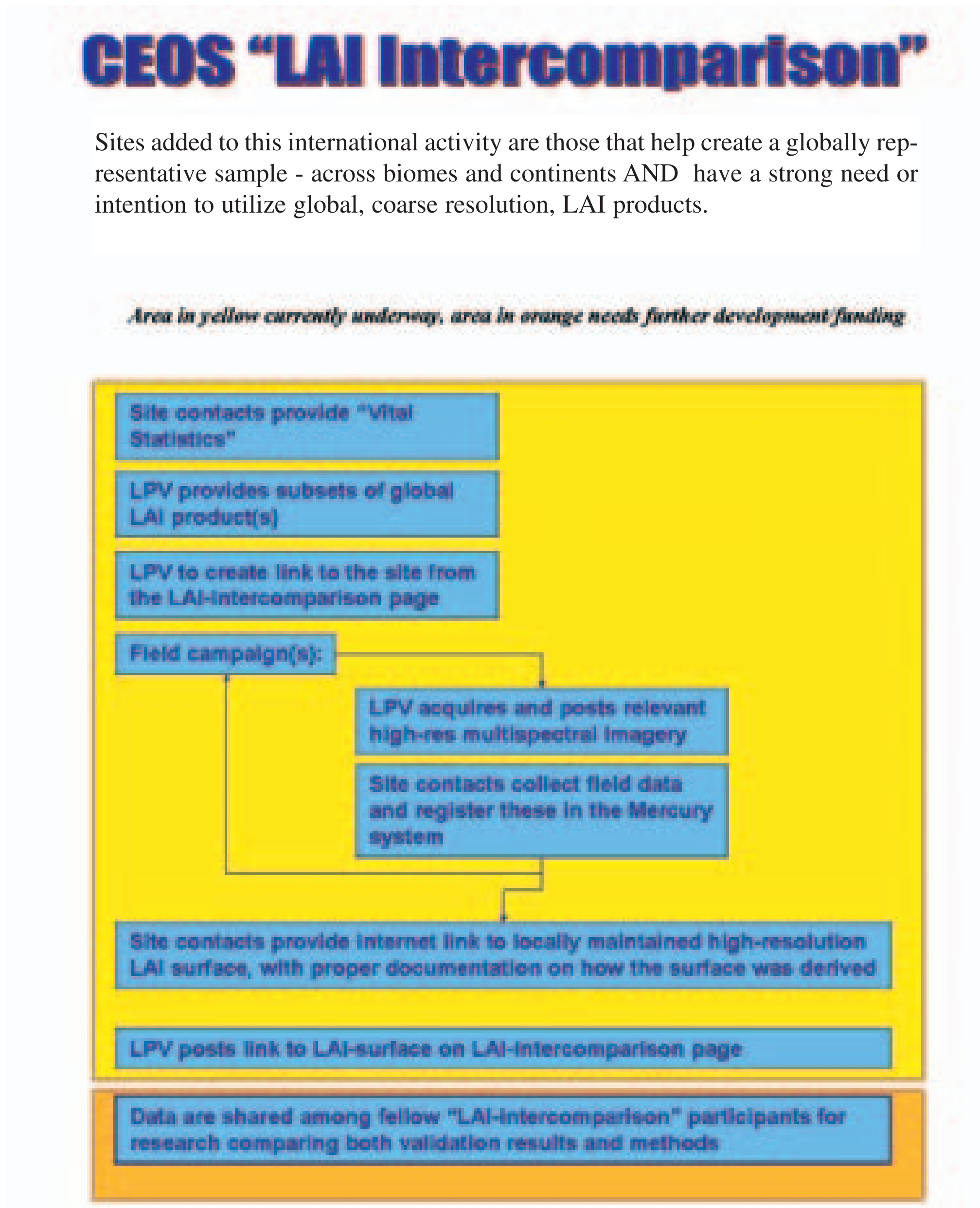

Figure 13. Strategy and flow diagram for LAI intercomparison effort.

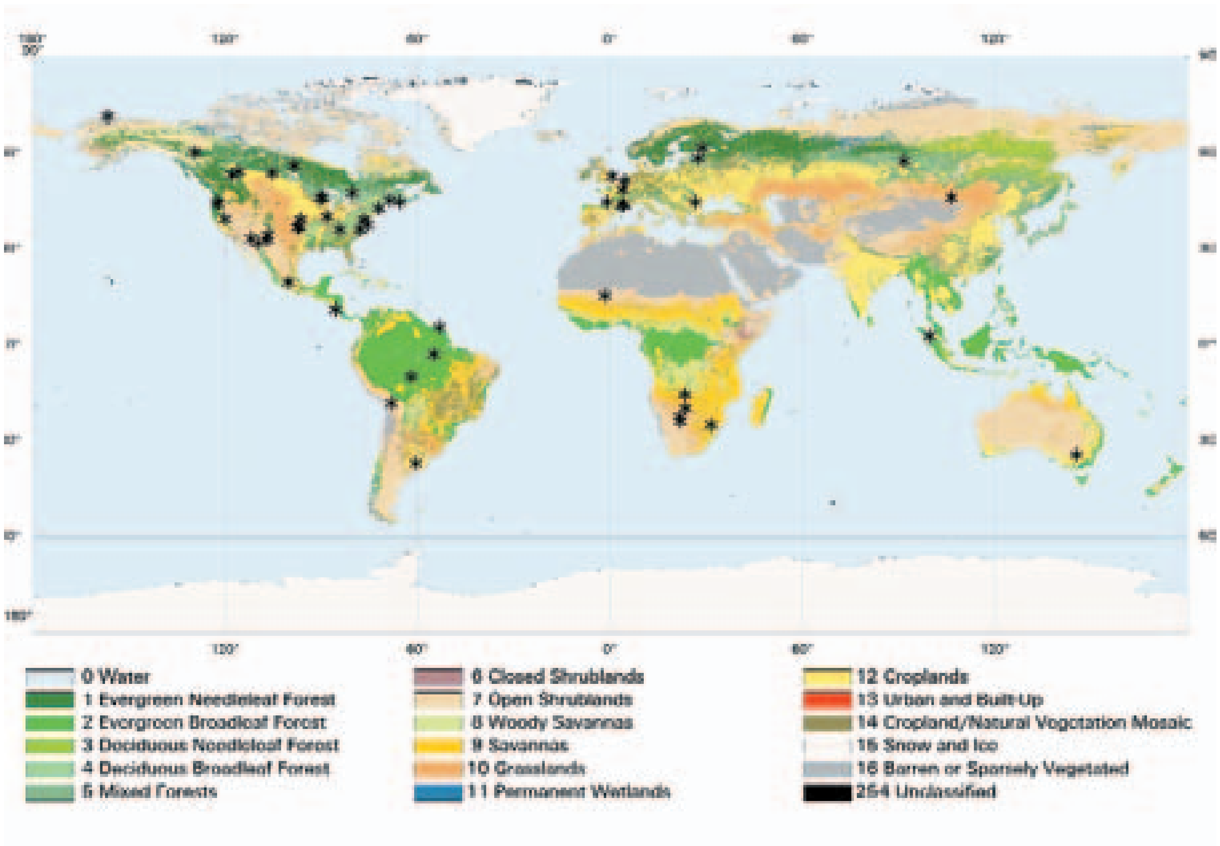

Figure 14. Proposed CEOS Land Validation Core Sites, shown on the MODIS land cover product (image provided courtesy of Boston University).

Future plans

MODIS land validation activities will continue to focus on the EOS Core Sites for validation in the MODIS/Aqua time frame. Additionally, the National Polar-orbiting Operational Environmental Satellite System Preparatory Project (NPOESS NPP) has included the EOS Land Validation Core Sites in their validation plans as primary targets for land product validation. GSFC will continue to play a leadership role in the CEOS Land Product Validation subgroup, looking to convene additional topical meetings and continuing the CEOS Land Product Validation Core Site and Intercomparison activities

References:

Justice, C.O. and Townshend, J.R.G. 1994. Data sets for global remote sensing: lessons learnt. International Journal of Remote Sensing. 15(17):3621-3639.

Morisette, J. Privette, J, and Justice, C., 2002, "A framework for the validation of MODIS land products", Remote Sensing of Environment, 83 (1-2) 77-96.

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Flight Experiment for Carbon Sequestration Studies: Using Combined VHF SAR & Lidar for Biomass Measurement

Forest biomass represents a significant pool of carbon recently removed from the atmosphere. The remote measurement of the above ground component of forest biomass is a primary goal of scientists interested in Earth's carbon cycle and, more recently as a consequence of international environmental treaties, a goal for both policy makers and commodity traders. The remote sensing of biomass using radar requires a balance between sensitivity to the vegetation and the ability to penetrate the vegetation. For this reason, the use of radar, which probes vegetation, is being explored as a means of measuring forest biomass. However, the majority of the currently available SAR systems use frequencies above 1000 MHz which saturate at relatively low forest biomass densities thereby missing most of Earth's standing biomass. To address this problem, the Biospheric Sciences Branch has developed a VHF (80-108MHz) radar system (BioSAR) designed specifically to measure the biomass of forest stands above 100 tons/ha. The instrument had its first flight test in 1997 over Big Thicket Forest Preserve in eastern Texas, and a full deployment to Central America in 1998 where it successfully produced biomass estimates of dense tropical forests within ± 10% of the field measured values (Figure 15).

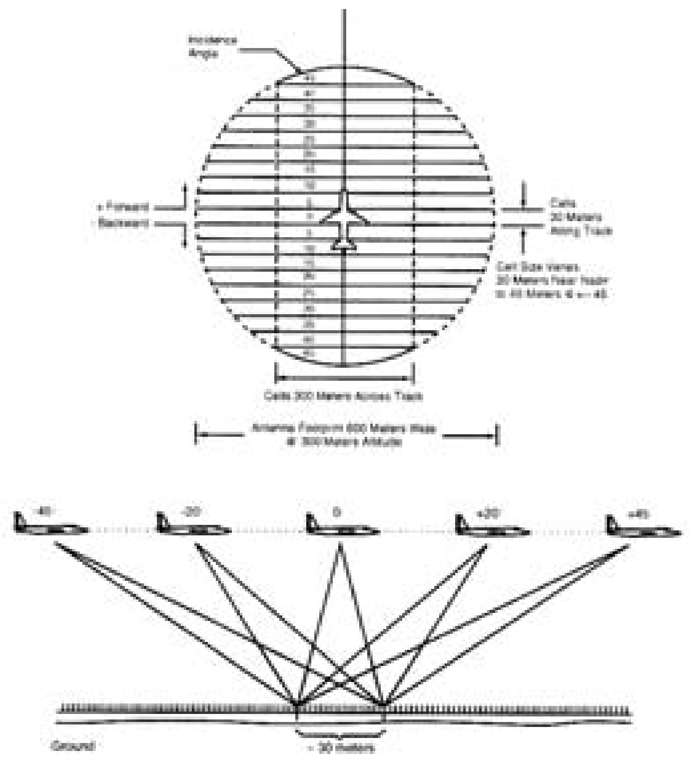

Figure 15. Top; BioSAR™ ground geometry - planar view. The antenna points straight down. As shown here, Doppler sorting is used to achieve 20 different look angles between +45° and –45° from the nadir in the along-track dimension. The resolution cell, after SAR processing, is approximately 30 meters in the along-track dimension, and 300 meters in the across-track dimension. While the actual across-track pattern of dimension of 600 meters (illuminated) is determined by the beam width and aircraft altitude it is nominally range gated to 300 meters for data collection. Bottom; BioSAR™ ground geometry - a single cell in cross-section. In this conceptual mode, a cell (30 m along track) is pulsed repeatedly using all six frequencies as the sensor flies over that point on the ground. The fore and aft angles can be logged separately or averaged together to make incidence angle bins in 5° intervals. Each cell has radar data for 6 frequencies acquired at multiple incidence angles.

As a result of this remarkable progress, a joint experiment has been implemented between the Biospheric Sciences Branch and the DoE's Oak Ridge National Laboratory to fly the BioSAR sensor along with a Profiling Airborne Lidar Sensor (PALS) in a series of flights designed to fully test the new combined system for carbon sequestration studies. The addition of the PALS system, which was also developed by the Biospheric Sciences Branch, will provide accurate forest height measurements (Figure 16). Please see the next article, titled "An Inexpensive, Portable Airborne Laser System For Forest Mensuration" for information about PALS. The data from PALS will be added to BioSAR's volumetric measurement capability and the combined data tested for making accurate forest stand biomass determinations in varying terrain conditions. The BioSAR and PALs sensors will be mounted on the Twin Otter aircraft leased by NASA and fly at least two forest sites with an established biomass/carbon cycle science research heritage. The effort benefits from a cost-sharing arrangement with the Department of Energy.

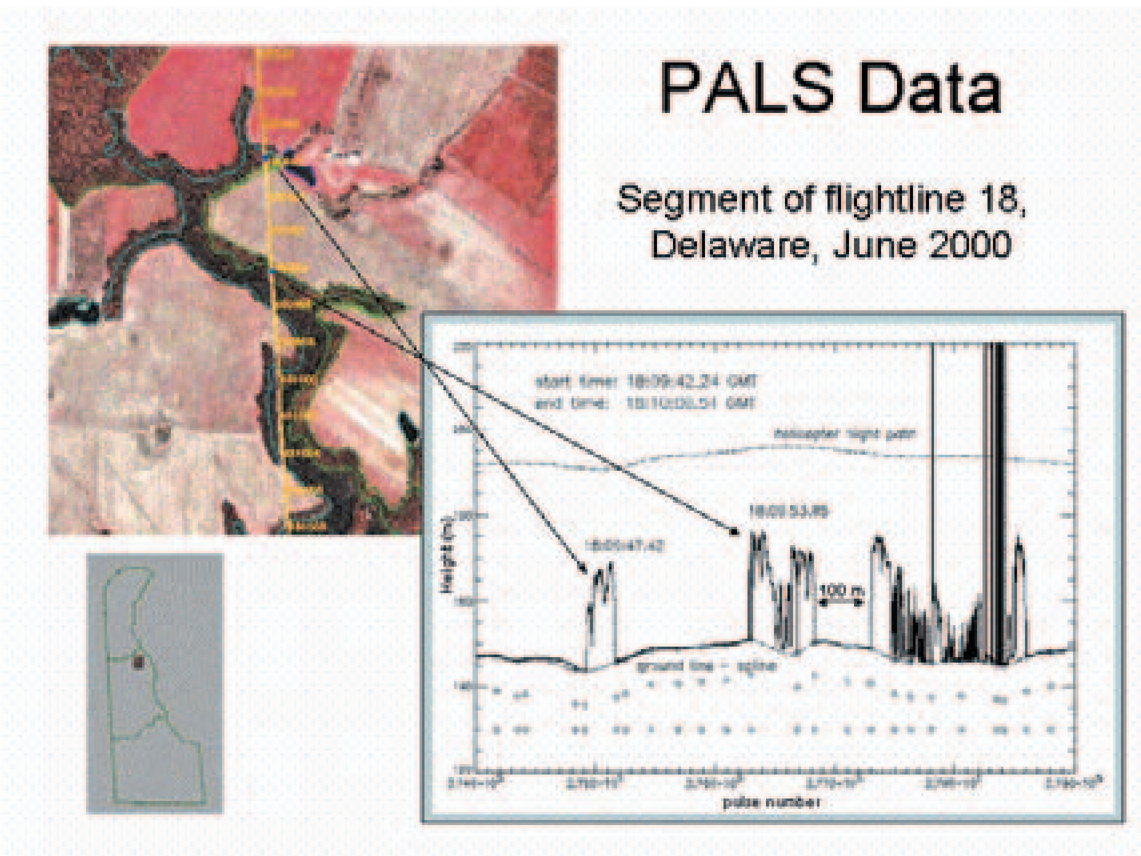

Figure 16. Laser profiling measurements will be acquired coincidently with the BioSAR measurements along the aircraft flight path. The laser is eyesafe in flight. The laser footprint directly beneath the aircraft will be 0.70m at a flight altitude of 300m AGL coincident temporally an spatially with the BioSAR footprint. PALS measures forest canopy height, height variability, and canopy density.

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An Inexpensive, Portable Airborne Laser System For Forest Mensuration

A simple, lightweight, inexpensive, portable airborne laser profiling system has been assembled from off-the-shelf, commercially available components. The system, which costs approximately $30,000 USD, is designed to fly aboard small helicopters and single or two-engine high-wing aircraft without airframe modification. The system acquires first-return range and amplitude measurements at data rates up to 2000 hz (operator-controlled) and has an operational envelope up to 300m above terrain. The airborne laser profiling system includes the laser transmitter/receiver, differential GPS, a CCD video camera and recorder, and a laptop computer, which interleaves and records the GPS and laser range/amplitude data. The portable airborne laser system - PALS - was designed to acquire forest height measurements along linear flight transects in order to conduct regional or subcontinental forest inventories worldwide. Height measurement accuracy is illustrated in Figure 17. This economical laser system now puts airborne laser mensuration within reach of operational foresters and researchers interested in making rapid forest structure and/or timber surveys in remote areas. PALS has been used to acquire over 5000 km of flight transect data over the state of Delaware.

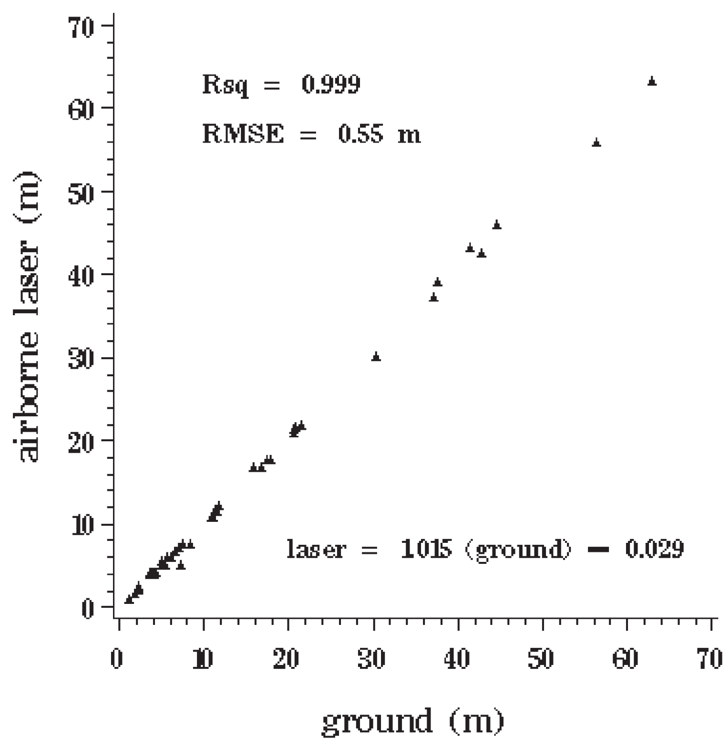

Figure 17. Comparison of building heights as measured by PALS and measured on the ground using a laser range/angle finder.

Reference:

Nelson, R.F., G. Parker, and M. Hom. 2003. A Portable Airborne Laser System for Forest Inventory. Photogrammetric Engineering and Remote Sensing, accepted for publication.

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Biomass Measurements from Lidar Mapping

In addition to providing a method to measure topography beneath vegetation cover, laser altimetry enables measurements of forest canopies that cannot be achieved by other remote sensing techniques. David Harding and collaborators at Oregon State University, the USDA Forest Service Pacific NW Research Station, and the Smithsonian Environmental Research Center, have published a series of articles that document this capability. Using field observations of forest properties and data acquired by the airborne Scanning Lidar Imager of Canopies by Echo Recovery (SLICER), methods were developed to predict forest attributes from the laser backscatter signal. As a first step, two properties of forest canopies important to ecosystem function are obtained from the backscatter signal: vertical transmittance of light (Parker et al., 2001) and height distribution of plant area (Harding et al., 2001).

Height indices derived from the plant area distributions have previously been shown to be an accurate predicator of above ground forest biomass for specific forest types (reviewed in Lefsky et al., 2002a). Lefsky et al (2002b) show that a single predictive relationship is equally applicable to three different closed-canopy forest biomes: temperate deciduous, temperate coniferous, and boreal coniferous (Figure 18). Based on regression of height indices and field observations of above ground biomass, mean height of the canopy squared (a proxy for height x stem diameter; a measure of volume) is the best laser-based predictor. The relationship is linear to high biomass levels and accounts for the observed variance to a high degree (80% to 90%). The generality of this result, at least for these three biomes, suggests that laser backscatter data for closed-canopy forests can be used to predict biomass without knowing the specific forest cover type sampled. The forest canopy measurement capabilities developed using airborne SLICER data will be applied on a global basis to laser altimeter data acquired by the Ice, Cloud and Land Elevation Satellite (ICESat).

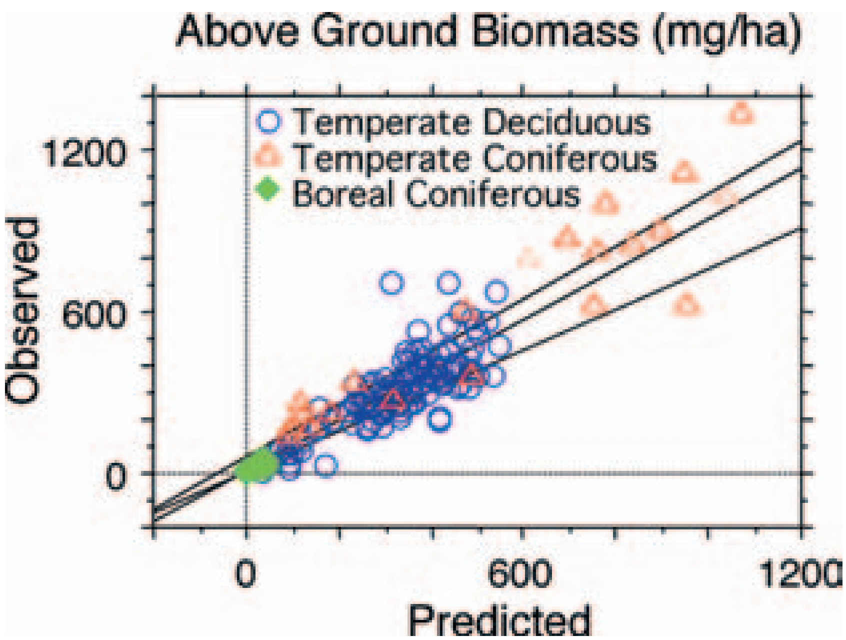

Figure 18. Relationship for three forest biomes between observed biomass and that predicted from laser backscatter height indices.

References:

Harding, D.J., M.A. Lefsky, G.G. Parker, and J.B. Blair, Laser altimeter canopy height profiles: Methods and validation for deciduous, broadleaf forests, Remote Sensing of Environment, 76(3): 283-297, 2001.

Lefsky, M.A., W.B. Cohen, G.G. Parker, and D.J. Harding, Lidar remote sensing for ecosystem studies, Biosciences, 52(1), 19-30, 2002a.

Lefsky, M.A., W.B. Cohen, D.J. Harding, G.G. Parker, S.A. Acker, and S.T. Gower, Lidar remote sensing of aboveground biomass in three biomes, Global Ecology and Biogeography, 11(5): 393-399, 2002b.

Parker, G.G., M.A. Lefsky, and D.J. Harding, Light transmittance in forest canopies determined using airborne laser altimetry and in-canopy quantum measurements, Remote Sensing of Environment, 76(3): 298-309, 2001.

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Data Processing

Another responsibility of the Laboratory is the development of new data processing techniques, and the development of new data sets. This is largely done in the Terrestrial Information Systems Branch, often in cooperation with the Biospheric Sciences Branch.

Global Data Processing for MODIS

MODIS (MODerate-resolution Imaging Spectroradiometer) instruments, launched on the EOS Terra and EOS Aqua spacecraft in December 1999 and June 2002, image the Earth in 36 spectral bands in visible through thermal wavelengths (459nm – 9.58µm) with spatial resolution of 250meters, 500meters and 1 kilometer. From an initial 70GB of raw instrument data, 44 global science products are produced with an average daily volume of 850GB from each MODIS instrument. These products extend the data record of products from heritage sensors, such as land surface reflectance, sea surface temperature and NDVI from AVHRR and ocean color from SeaWiFS, and offer finer spatial resolution, better calibration and more precise Earth-location of pixels.

In 2002, the MODIS team focused its efforts on improving science quality, completing a global validation of EOS Terra products and modifying formats to make land products easier to use by the community. Before the first major reprocessing of MODIS products began, over 170 changes were made to the 60 science applications programs that create global land, ocean and atmosphere products. During the reprocessing a 64 processor Silicon Graphics Origin 3000 supercomputer and a 200 processor Linux cluster were used to reprocess the 3 year data record from Terra at the rate of 8 data days per day. Over 3 TB (trillion bytes) of data products produced daily were distributed to MODIS quality assessment teams, the MODIS science team and to Distributed Active Archive Centers (DAACs), which archive the products and distribute them to the public. Two globally validated products that were highlights of the 2002 reprocessing campaign are sea surface temperature (SST) products achieving accuracies to within 0.3^{o}K (a significant improvement over SST from precursor instruments) and atmospherically corrected land surface reflectance with absolute accuracies to better than 3%. SST is an important parameter for models of global climate and weather prediction, and the land surface reflectance product is the foundation for all land products that deal with vegetation, such as vegetation indices, land cover type and change, leaf area index and net primary production.

An essential component in improving the quality of MODIS products has been a rigorous process of product quality assurance involving unit testing of science software, large scale science tests on all software and a program of continuous product quality monitoring and validation. Figure 19 below summarizes this process. The numbers in colored ovals in the left hand side of the figure represent software changes. Note slightly more than a third of the software changes submitted by the science team survive the testing process and run in the production system.

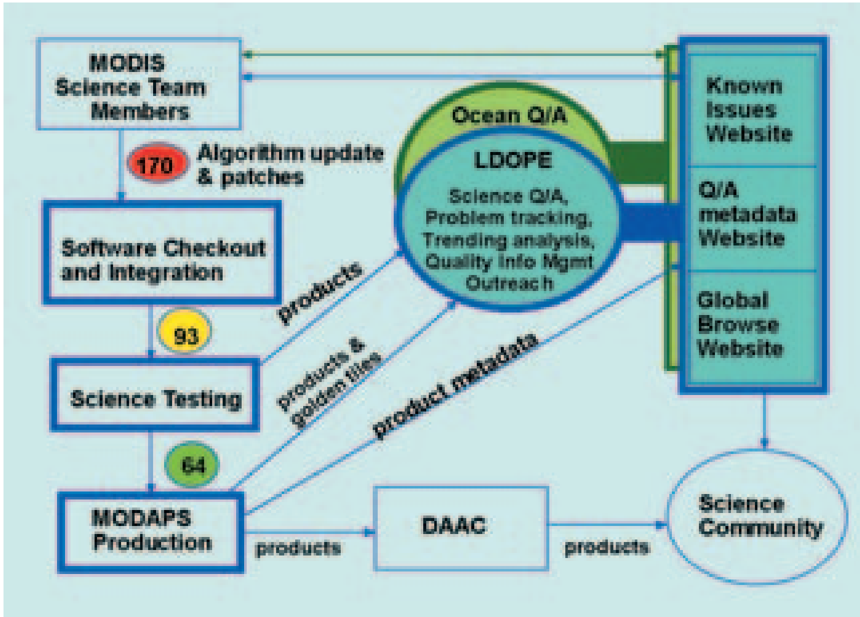

Figure 19. Quality Assurance

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MODIS Rapid Response System

A collaboration between NASA, the University of Maryland, and the USDA Forest Service led to the development of a processing system capable of generating near-real-time products from MODIS data to support the Forest Service in its effort to better allocate firefighting resources across the United States. The Rapid Response System (http://rapidfire.sci.gsfc.nasa.gov/), located at NASA/GSFC in the Terrestrial Information Systems Branch, started operating in 2001. 2002 represented a continuation of the effort undertaken in 2001, and was mostly focused on streamlining the activities prototyped during the first year, on augmenting the system with new products, and on developing new application partnerships.

The Rapid Response System now generates a fire detection product, a corrected reflectance product, and a vegetation index product in near-real-time for most of the Earth's land surfaces, from both the Terra/MODIS and the Aqua/MODIS instruments. The Rapid Response System receives MODIS level-0 data from NOAA's MODIS Near-Real-Time System from the entire Earth within 4 hours of data acquisition. The subset of the data containing continents and major islands is processed upon reception.

Fire locations are retrieved using a fire detection algorithm. Those fire locations are immediately communicated to the USDA Forest Service Remote Sensing Center in Salt Lake City. The Forest Service incorporates fire locations into a Geographic Information System (GIS) and generates regional fire maps twice daily. These maps represent the fires detected by MODIS overlaying various geographic layers (see Figure 20). Fire maps are made available to the fire managers and are used to provide a synoptic view of the fire situation and help determine the best strategy to allocate fire fighting resources. The process is all automated from the data acquisition to the generation of fire maps.

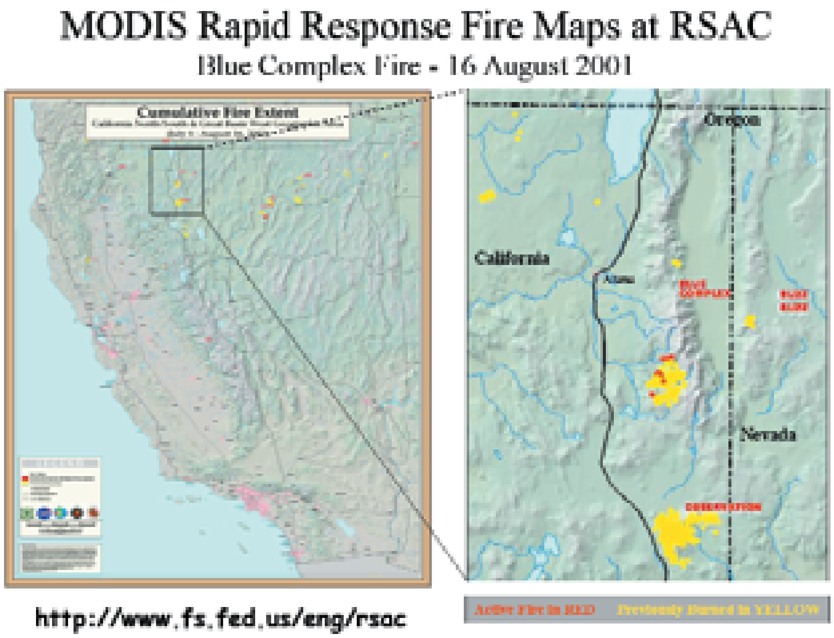

Figure 20. MODIS Rapid Response Fire Maps at RSAC.

MODIS has now become a tool recognized at the highest level of the national firefighting community. It is advertised by the National Interagency Fire Center (NIFC) as one of the main sources of fire data (http://www.nifc.gov/firemaps.html). The MODIS Rapid Response fire data is now integrated in the Geospatial Multi-Agency Coordination (GEOMAC) system, the main web-based mapping tool offered to the fire managers (http://geomac.usgs.gov/).

The Rapid Response Team packaged and delivered a version of the processing software working with MODIS Direct Broadcast data. The Forest Service began operating two Direct Broadcast receiving stations in 2002 (Remote Sensing Applications Center, Salt Lake City, UT, and Fire Sciences Lab, Missoula, MT) and now runs the Rapid Response software in both locations, and operationally generates fire locations and corrected reflectance within minutes of data acquisition in the region covered by the receiving range of each dish.

The Rapid Response System also communicates the fire locations detected by MODIS to the University of Maryland where the data are ingested by a Web-GIS system and made available to the public and the fire community through a web interface. In particular the University of Maryland has developed a collaboration with the Global Observation of Forest Cover (GOFC) fire partners, regrouping a number of regional fire groups across the world.

Another key product of the Rapid Response System is the corrected reflectance product. The MODIS top-of-the-atmosphere calibrated radiances are corrected for various atmospheric effects to produce this corrected reflectance, from which it is possible to generate images of the Earth. High-resolution imagery from all the data processed by the Rapid Response System is automatically made available on the Rapid Response web site (http://rapidfire.sci.gsfc.nasa.gov/realtime/). That near-real time imagery is used by the fire community in addition to the fire locations to help interpret fire situations, determine the presence of smoke, evaluate the burned area, etc. The near-real-time imagery is also used by other science communities. For example, it is now used routinely by the Dartmouth Flood Observatory to map flooded areas (http://www.dartmouth.edu/artsci/geog/floods/).

Hand-picked imagery is also posted in the Rapid Response Image Gallery (http://rapidfire.sci.gsfc.nasa.gov/gallery/). 1600 gallery images were generated in 2002. A large number of the Rapid Response gallery images cover newsworthy events related to natural hazards (see Figures 21, 22, and 23). The Rapid Response System provides the backbone of the Earth Observatory's Natural Hazards section (http://earthobservatory.nasa.gov/NaturalHazards/) and is also the main MODIS contributor to the Visible Earth image database (http://visibleearth.nasa.gov/). More than fifty images were posted as image of the day by the Earth Observatory. Twenty-five images from the Rapid Response system were featured on the GSFC web page in 2002.The Rapid Response System counted a number of successes in the media in 2002, with each time many appearances on major TV stations and newspapers: Sydney fires in January, Colorado fires in mid-June, Arizona fires in end-June, Quebec fires in July, Mt. Etna eruption in October. Almost 900,000 images were downloaded from the Rapid Response web site by approximately 45,000 different visitors in 2002.

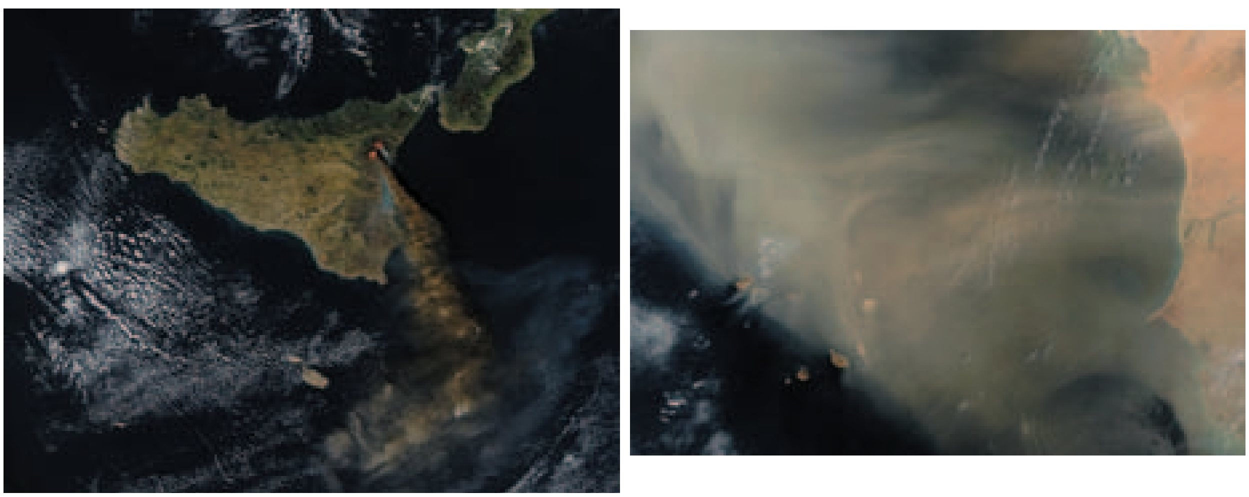

Figure 21. (Left) Eruption of Mt. Etna in Sicily (10/28/02). (Right) Dust Storm off West Africa (03/02/03).

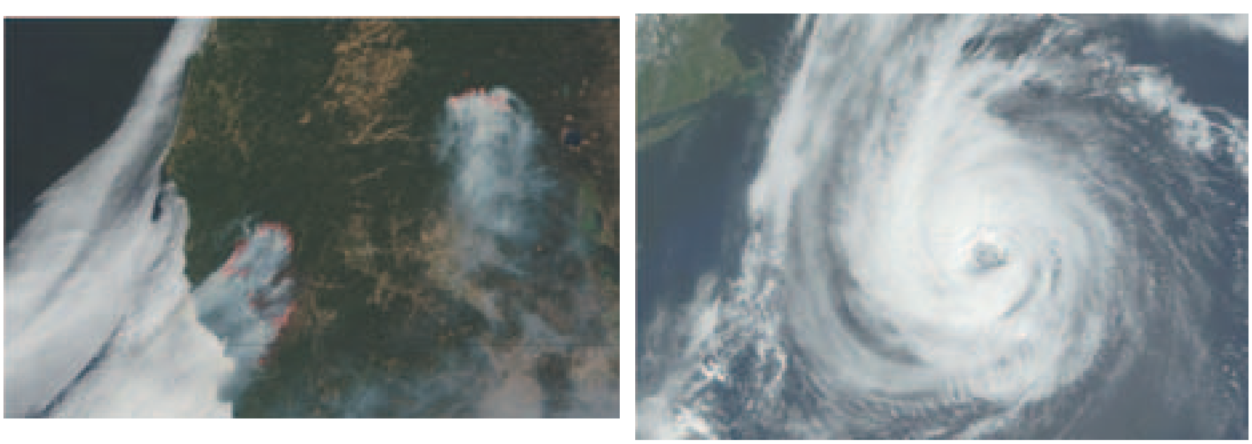

Figure 22. (Left) Biscuit and Tiller Fires in California and Oregon (08/14/02). (Right) Example of 250m Corrected Reflectance Product, Hurricane Erin (09/11/01).

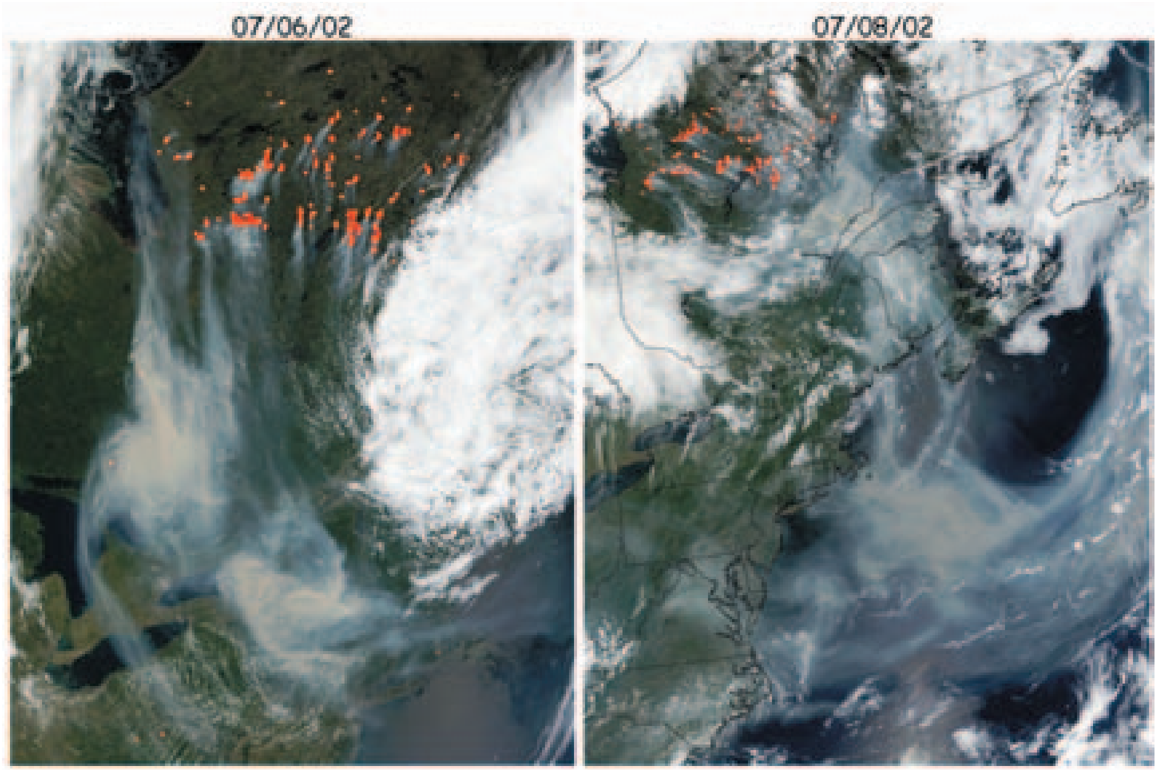

Figure 23. Fires and smoke across Quebec and Northeast US.

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Ozone Monitoring Instrument Science Investigator's Processing System

Rapidly evaluating possible improvements to algorithms for measuring ozone, aerosol, and other products is now possible. The OMI Science Investigator's Processing System, OSIPS, developed by the Terrestrial Information Systems Branch (Code 922) provides both high speed processing and rapid data delivery to the scientist's desktop computers. The OMI DAta Processing System, OMIDAPS, combines multiple Intel processors in a next generation system based on the MODis Adaptive Processing System, MODAPS. With the power of OMIDAPS it is possible to process twenty-two years of data from the Total Ozone Mapping Spectrometer in less than three days instead of the three months it used to take. The OSIPS and the scientists in the Atmospheric Chemistry Branch (Code 916) share access to a newly installed high speed Fibre Channel disk. Data sets are reprocessed with evolving algorithms in the OSIPS and then pushed onto the shared disk and immediately available to scientists evaluating them in a different building. This shared disk will also support the adaptation of the algorithms for the Ozone Monitoring Instrument (OMI) after it is launched on the EOS Aura spacecraft in 2004.

One tool now available allows scientists to examine the effect of a small change in an algorithm by viewing a movie of the difference between outputs of the two algorithms for every day in the twenty-two year period. Figure 24 illustrates this with total ozone and surface reflectivity data from the TOMS instrument on the Earth Probe satellite. The top left and right images show the new values of the total ozone and the surface reflectivity for the first day of 1998. The bottom two images show the relative difference between two candidate algorithms. Examining the images for the entire period revealed a small problem confined to the Polar Regions. Subsequent analysis identified the cause of the difference and a revised algorithm has been developed and tested to process data from the upcoming Ozone Measuring Instrument, OMI, to be flown on the AURA spacecraft in 2004.

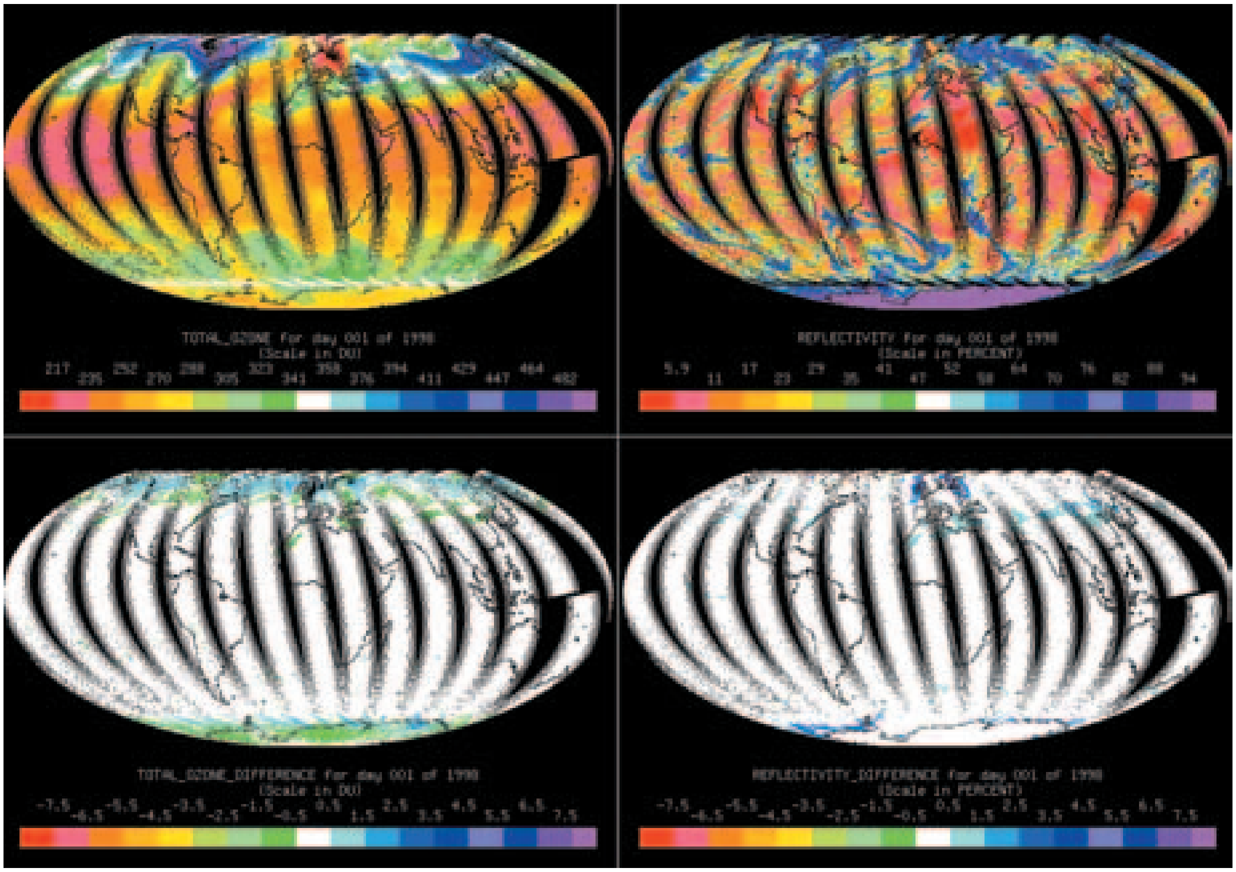

Figure 24. Total ozone and surface reflectivity data from the TOMS instrument.

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Satellite Programs

A major activity in Biospheric Sciences concerns management of present and future satellite missions, either as Project Manager, Project Scientist, and Instrument Scientist or in the calibration and validation of the data. Following are descriptions of such activities, ranging from currently orbiting satellites to planned missions.

Flight Programs

Landsat and the Land Cover Satellite Project Science Office

Thirty years ago, on July 23, 1972, NASA launched the first Landsat satellite, beginning what is now the longest record of the Earth's continental surfaces as seen from space. It is a record unmatched in quality, detail, coverage and value. Today, both Landsat-5 and Landsat-7 continue to operate, routinely gathering multispectral imagery of the globe for environmental assessments, land-cover mapping, and commercial applications. Since launch in April 1999, some 291,000 Landsat-7 ETM+ scenes had been archived at the USGS EROS Data Center (EDC) in Sioux Falls, South Dakota, which also holds an archive of over 500,000 Landsat-5 TM scenes.

At NASA GSFC, the Land Cover Satellite Project Science Office (LPSO) is responsible for long-term calibration/validation of Landsat-7 ETM+ data, and ensuring the scientific success of the Landsat-7 mission. Working jointly with personnel from the USGS (which is responsible for mission operations), the LPSO team tracks the radiometric and geometric character of acquired data, and makes recommendations to enhance their quality and scientific utility. As described in other sections of this document, the LPSO is also actively involved in the NMP Earth Observing-1 mission, and in formulating the Landsat Data Continuity Mission, the designated follow-on to Landsat-7.

Key Landsat-related accomplishments during 2002 included:

Landsat On-Orbit Performance and Calibration: The Landsat-7 ETM+ on-orbit performance and calibration is evaluated and maintained through the cooperative efforts of LPSO at Goddard Space Flight Center and USGS via the Landsat-7 Image Assessment System (IAS) at the EROS Data Center. NASA contributes primarily radiometric expertise and analyses, and funds and coordinates the acquisition and processing of vicarious radiometric calibrations via an RTOP under the Land Cover and Land Use Change program. USGS operationally maintains and updates the calibrations and processing systems, conducts the operational processing and provides primarily geometric expertise and analyses. Vicarious radiometric calibration efforts are conducted by the University of Arizona (K. Thome), Rochester Institute of Technology (J. Schott), NASA/Jet Propulsion Laboratory (F. Palluconi) and South Dakota State University (D. Helder). The results reported at recent meetings have shown that: (1) the ETM+ reflective calibration continues to be excellent with accuracy to better than 5%, (2) the stability of the bands is better than 0.5% per year, (3) the ETM+ thermal band has an accuracy compared to ground measurements of better than 0.6 degrees K and (4) the stability of the thermal band is better than 0.1% per year. The teams have recommended that the current calibration be retained for the reflective and thermal bands as the significance of the currently reported trends is unclear.

A new effort to develop an atmospheric correction tool for the ETM+ single thermal band was initiated in 2002. This methodology accesses the global National Centers for Environmental Prediction (NCEP) atmospheric profiles and can calculate atmospheric correction parameters for any Landsat-5 or Landsat-7 thermal band image for which there is a coincident atmospheric profile. This tool can be accessed via the Landsat web site (http://landsat.gsfc.nasa.gov/).

The LPSO and the USGS EDC have also been involved in an effort to reconstruct the 19-year radiometric calibration history of the Landsat-5 Thematic Mapper. The team listed above, as well as P. Teillet from the Canada Center for Remote Sensing, are involved. The reflective band record has been reconstructed from the data from the best-behaved TM internal calibration lamp combined with an absolute anchoring to the Landsat-7 ETM+ calibration during simultaneous imaging of the two instruments in June 1999. The new procedure will replace the scene-by-scene use of the internal calibrator data from all three lamps. EDC expects to have the new calibration processing methodology in place by Spring 2003. Data processed after this point in time will be tied to the Landsat-7 calibration and will provide a radiometrically consistent data set for Land Cover Studies since 1984.

Landsat Team Receives Pecora Award: Darrel Williams, Landsat Project Scientist from NASA GSFC, and RJ Thompson, Director of the USGS EROS Data Center were chosen to jointly receive the William T. Pecora Award for 2001 on behalf of the entire Landsat-7 Team at the bi-annual Pecora Conference which was held in Denver, Colorado in mid-November, 2002. The Pecora Award is presented annually by the Department of the Interior (DoI) and NASA to recognize outstanding contributions by individuals or groups toward the understanding of the Earth by means of remote sensing. The Pecora Award was established in 1974 to honor the memory of Dr. William T. Pecora, former Director of the U.S. Geological Survey and DOI Under Secretary, whose early vision and support helped establish what we know today as the Landsat satellite program.

Validation of the Landsat-7 Long-term Acquisition Plan: Unlike coarse-resolution sensors like MODIS and AVHRR, Landsat sensors do not acquire data at all times, but instead are switched on to acquire particular scenes of interest. The Landsat-7 Long-term Acquisition Plan (LTAP) specifies where and when Landsat-7 ETM+ data are to be acquired, in order to create a scientifically optimal global archive. In general, the LTAP seeks to avoid cloud contamination in Landsat imagery by "looking ahead" using NOAA cloud predictions, and seeks to acquire a seasonally-refreshed global archive, concentrating on particular intervals when local vegetation shows greatest change (dynamics) as derived from AVHRR NDVI data.

Although anecdotal evidence has suggested that the Landsat-7 LTAP is a success, 2002 marked the first rigorous validation of its performance. Dr. Samuel Goward (U. Maryland) and Terry Arvidson (Lockheed-Martin) led the validation activities, and were supported by LPSO personnel Darrel Williams, Brian Markham, Richard Irish, Jeffrey Masek, as well as personnel from the Landsat Mission Operations Center (MOC) and USGS EDC. The group concluded that the LTAP was generally doing an excellent job of providing seasonal, global coverage. However, too few scenes were acquired for the northern boreal forests, while too many scenes were acquired of desert environments (North Africa, Arabia). A boreal acquisition campaign for 2003 will attempt to remedy this situation. The validation activity also concluded that cloud avoidance was working well (a 25% decrease in archive cloud contamination compared to a non-avoidance scenario), and that there was no scientific need to gather data for which the predicted cloud-cover was greater than 80% outside of the United States. This change was implemented in the Landsat-7 MOC during 2002. A separate validation of the Landsat Automated Cloud Cover Assessment (ACCA) system indicated that cloud cover figures calculated from acquired images were accurate to within 10%, 95% of the time.

Earth As Art: In celebration of the 30th anniversary of the first Landsat launch, NASA and the USGS created an exhibit called "Landsat: Earth as Art." The exhibit highlighted images that were selected on the basis of aesthetic appeal, and also served to introduce the public to Landsat data. The exhibit opened July 17 at the Library of Congress in Washington, D.C. A selection of the "Landsat: Earth as Art" images was on display in the Russell Office Building Rotunda in Washington, D.C., July 20 - 26, and throughout the fall at the Arizona Science Center in Phoenix, Ariz. Another exhibit was recently on display in Rapid City, S.D., at the Children's Science Center. During December, 2002, the exhibit received considerable media attention, with coverage by CNN, CBS, Newsday, and others, resulting in numerous downloads of imagery from the "Earth as Art" website.

Australian Greenhouse Office Use of Landsat Data: Dr. Darrel Williams served on the review panel for the Australian Greenhouse Office's "Carbon Accounting Team" in May 2002. The Greenhouse Office has created a multi-temporal Landsat data base for the entire continent of Australian to assess the extent and productivity of vegetation communities within Australia since the early 1970's, in support of the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol. This multitemporal data set may be the most robust continental scale Earth observation data set of its type ever assembled, and sets a new standard for scientific and policy use of the Landsat archive.

NSLRSDA Archive Advisory Committee: The U.S. Geological Survey's (USGS) National Satellite Land Remote Sensing Data Archive (NSLRSDA) was established in 1992 to maintain a permanent, comprehensive Government archive of global Landsat and other land remote sensing data. Drs. Darrel Williams of NASA GSFC and Samuel Goward, University of Maryland have served on the Archive Advisory Committee (AAC) for several years, and in 2002, they focused their attention on assessing the robustness of the annual global Landsat MSS and TM coverage available in the Archive at EDC. Their activities will continue in 2003, and working in concert with the Chief Archivist at EDC, John Faundeen, they plan to identify geographic "gaps" in the EDC archives and to approach appropriate International Ground Stations to determine if they have coverage in their respective archives that may be used to fill these gaps.

Landsat Global Data Working Group: Drs. Jeffrey Masek and Darrel Williams (NASA GSFC) participated in the Landsat Global Data Working group, chaired by Dr. Anthony Janetos (Heinz Institute), which was charged with developing an acquisition and analysis strategy for the Year 2000 Landsat global data purchase. This dataset will provide global, orthorectified Landsat coverage for the globe for the year 2000, providing a complement to the existing 1990 GeoCover product.

Additional Outreach Activities: During 2002, the LPSO group undertook a variety of outreach activities to educators, policy-makers, and the general public, including:

- GSFC Colloquium on Landsat's 30th Anniversary with Darrel Williams, Vincent Salomonson, and David Skole (U. Michigan)

- Production of "zoom in" visualizations for The Super Bowl and Winter Olympics

- Presentations to high school science teachers on optical remote sensing and Landsat

- Preparation of visual displays for NASA HQ for Congress

- Presentation to Native American students using Landsat data for habitat analysis

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The Earth Observing One (EO-1) Base Mission

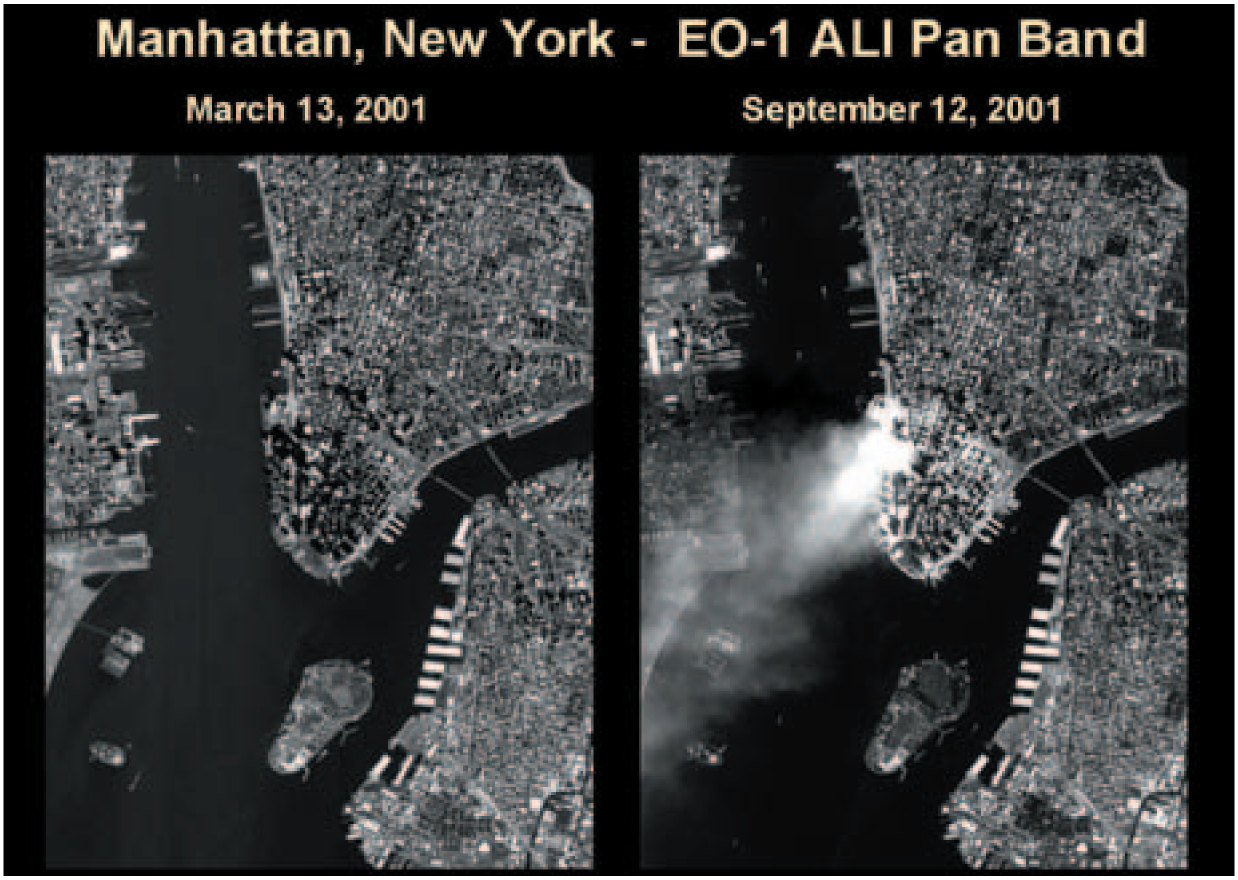
The Earth Observing One (EO-1) Base Mission met all of its proscribed goals by the end of calendar year 2002. The original intent of this mission was to validate the onboard technologies through one year of data collection followed by an additional year of analysis. EO-1 was launched from Vandenberg Air Force Base in November 2000. The satellite was tasked to collect data for validation by the Science Validation Team (SVT) during 2001. Early in 2002, processing and distribution of EO-1 data was turned over to the USGS EROS Data Center (EDC) as part of the EO-1 "Extended Mission." The analysis phase of the Base Mission continued through 2002, culminating in the final SVT meeting, held in November 2002.

The SVT completed their analyses of the data gathered during the entire Base Mission period from December 2001 through January 2002 at the end of 2002. The emphasis of the validation is on characterizing the performance of the EO-1 instruments in acquiring remotely sensed measurements contributing to a variety of important earth science applications. The results of many of these studies were presented at IGARSS-2002 EO-1 sessions in June 2002. A special issue of the IEEE Transactions on Geoscience and Remote Sensing (TGARS), devoted to the SVT EO-1 validation results, will appear in early 2003.

The EO-1 Extended Mission offers users in various government agencies, the commercial sector and general research community the opportunity to investigate the potential of applying technology and techniques developed for EO-1 to solving problems in their own areas of interest. With the demise of the Lewis and Orbview-4 spacecrafts, EO-1 uniquely offers a space-borne spectral imaging capability that is not currently available from any other source. The EO-1 Mission requirements specified 1000 acquisitions to yield 200 scene comparisons with Landsat 7. At the end of 2002, EO-1 had acquired almost 7000 scenes. Researchers wishing to schedule acquisitions during the Extended Mission or order data acquired by others during all phases of the mission should access the EDC website at http://eo1.usgs.gov/.

The EO-1 Mission has proven to be highly successful in identifying technologies and techniques to be employed in future earth observing missions. It has provided a test-bed for refining specifications and expectations in the Landsat Data Continuity Mission (LDCM). It has provided a powerful platform for investigating the power of space borne spectral imaging for extracting information about surface processes. The SVT conducted a substantial effort to explore and exploit the uses of spectral imaging and vastly improved multispectral radiometric resolution for earth science applications during the last half of 2002.

Since EO-1 was pointable, it proved to be a valuable tool for monitoring catastrophic events. In addition, the inherent band-to-band registration, due to the ALI chip design and platform yaw steering capability, facilitates the creation of pan-enhanced color composites. Figures 25 through 28 show examples of these capabilities.



Figures 25. World Trade Center, before and after September 11th attack.

Figure 26. World Trade Center, after September 11th attack. Color Composite.

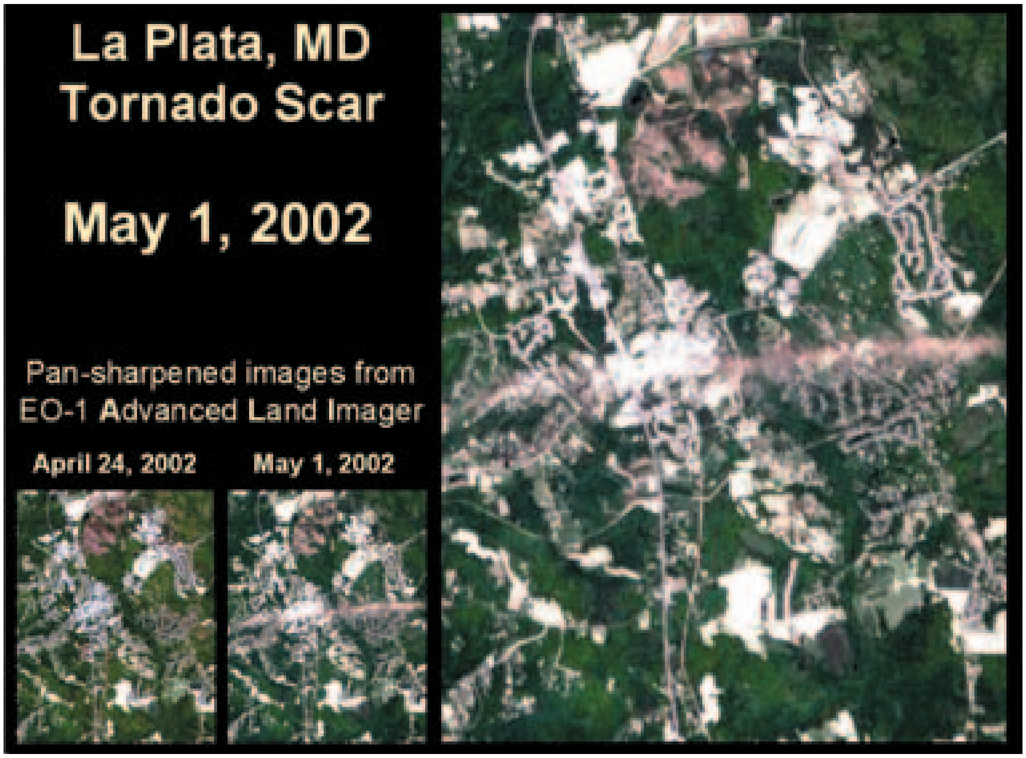


Figure 27. La Plata, Maryland tornado track.

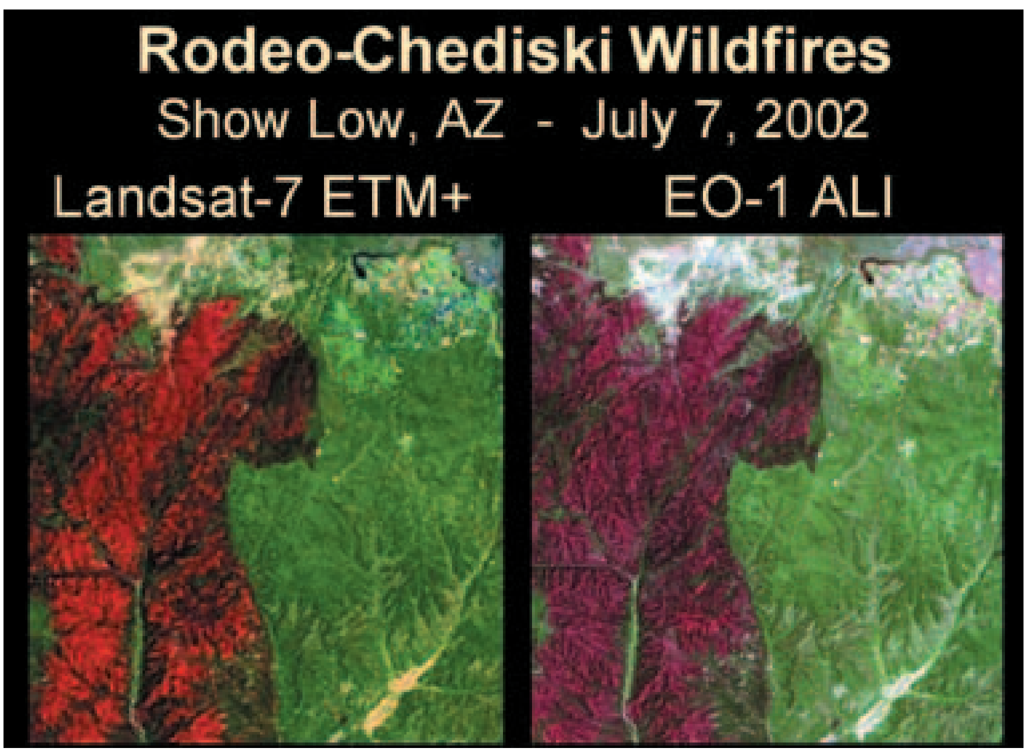


Figure 28. EO-1 / Landsat wildfire delineation. Red coloration indicates burned areas

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EOS Terra Mission

Terra was launched in December 1999, and is the flagship spacecraft for NASA's Earth Observing System Program. The five Terra Spacecraft instruments have been providing scientific data since the instrument doors were opened on February 24, 2000. As of January 2003, all Terra systems were nominal and all instruments were collecting science data. During 2002, the Terra equator crossing time was adjusted to be 10:30 am + 5minutes, through a series of inclination adjust maneuvers. A few instrument anomalies were dealt with this past year. The MODIS instrument scientific formatting equipment was experiencing a problem with frequent resets. Switching to the redundant side system alleviated this problem. MODIS has experienced no other significant problems since this anomaly was resolved. MOPITT experienced a brief cooler malfunction in December. Despite these and earlier problems MOPITT is acquiring science data for both carbon monoxide and methane. MISR and CERES operated throughout the year with no significant problems.

The year 2002 highlights include release of several important scientific data sets. ASTER nearly completed their first global acquisition data set. Through a new agreement with Japan, U.S. Geologic Survey's Eros Data Center (EDC) is now able to process level 1B data. ASTER now charges $55 a scene through EDC. However, NASA investigators do not have to pay this fee. CERES continued to produce validated ERBE like products and is preparing to release new data products. MISR released global cloud, surface and aerosol products. MODIS released validated data sets for several science products, including surface albedo, vegetation leaf area index, sea surface temperature, and aerosol optical depth. MOPITT is producing carbon monoxide data products and releasing them through the Langley DAAC. Terra product definitions and status of Terra Data Products are found on the Internet at:

http://eosdatainfo.gsfc.nasa.gov/eosdata/terra/terra_dataprod.html

The MODIS direct broadcast system continues to provide critical wildfire data to U.S. and foreign fire services. The Terra Flight Operations group was able to successfully negotiate a waiver from NASA's Deep Space Network to allow direct broadcast data over the Canberra, Australia antenna during the recent and severe fire season. Previous agreements stated that Terra must cease direct broadcasting while over the DSN antennae thus severely restricting use of MODIS for fire fighting activities. MODIS is also being used extensively, along with Landsat and other higher resolution instruments, to assess post-fire forest conditions by the U.S. Forest Service Burned Area Emergency Rehabilitation Project.

A new "Natural Hazards" site was opened by the Earth Observatory Web site. This site highlights the use of satellite data for monitoring floods, volcanoes, storms, wild fires and other observable events. For the first time, MOPITT was able to release image data to support news events on the Earth Observatory Web site. In addition the Earth Observatory was awarded a 2002 Webby Peoples Choice Award by The International Academy of Digital Arts and Sciences. The site can be viewed at http://earthobservatory.nasa.gov/

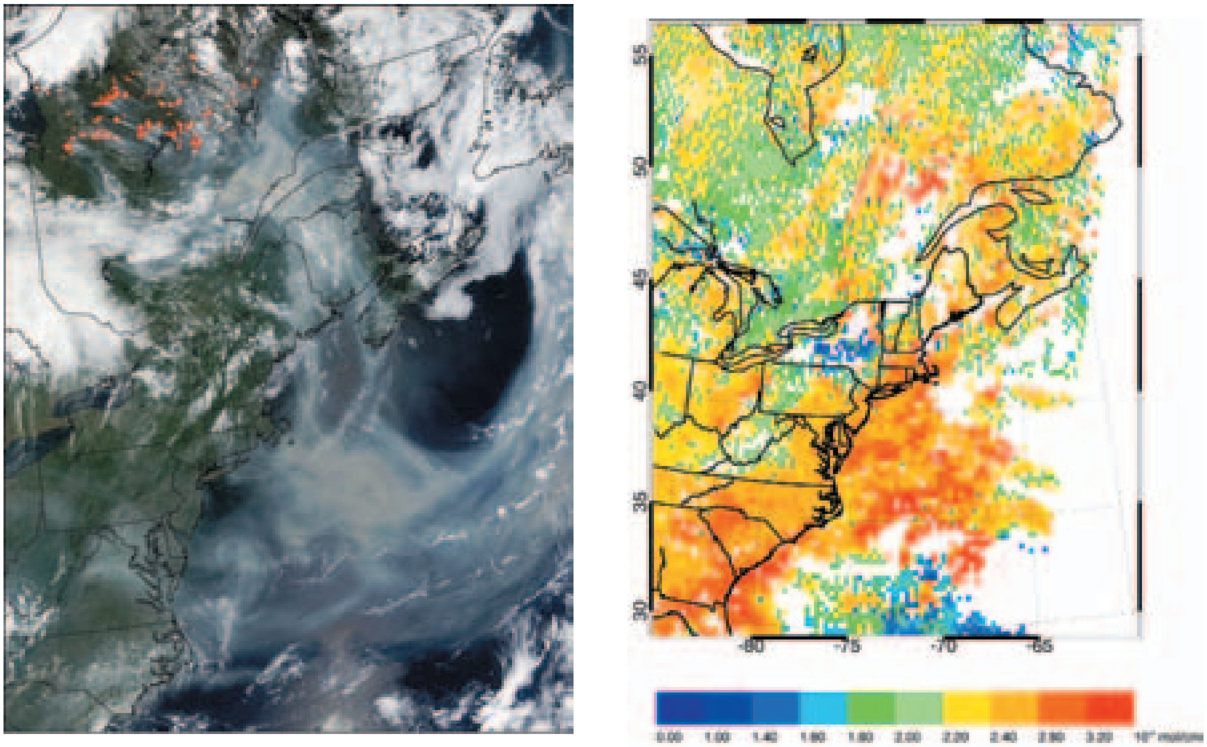

Figure 29. Left, Terra Moderate Resolution Imaging Spectroradiometer (MODIS) image from July 8, 2002, shows smoke from wildfires (red dots) in Québec, Canada, drifting southward over the eastern United States (image courtesy of Terra MODIS Science Team). Right, MOPITT total column Carbon Monoxide image for July 1-8, 2002 period (image courtesy of Terra MOPITT Science Team).

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Planned Programs

Landsat Data Continuity Mission (LDCM)

The Landsat Data Continuity Mission (LDCM) will be the follow-on mission to Landsat 7 and will begin providing data by March 2007. NASA traditionally specifies the design of the spacecraft, instruments, and ground systems acquiring data for its Earth science mission. Landsat 7, for example, is a government specified, owned, and operated satellite system. In contrast NASA will procure LDCM data from a privately-owned and commercially-operated remote sensing satellite system. NASA has specified the content, quantity, and characteristics of LDCM data to be delivered by a commercial system operator. A NASA-selected commercial operator will deliver specification-compliant data to NASA's partner in the Landsat Program, the United States Geological Survey (USGS). The USGS will archive the LDCM data at its EROS Data Center (EDC) in Sioux Falls, South Dakota and will distribute Level 1 data products (that is, radiometrically corrected data registered to cartographic projections) to the general public on request. LDCM data will be available from the EDC no later than March 2007. The objective of this new procurement approach is to not only ensure Landsat data continuity for Earth science, but to also foster growth of the commercial remote sensing market place. The hope is that the commercial operator will share the cost and risk of the LDCM with the government and that ultimately Landsat like data will be available from purely commercial sources.

NASA is taking a two-step approach to the LDCM data procurement. The first step, a formulation phase, was conducted in 2002. NASA released a Request for Proposals for formulation phase studies on November 01, 2001. Proposals were received on December 19 and proposal evaluations were performed during early 2002. On March 15 NASA announced the selection of two private companies, Resource 21 of Engelwood, Colorado and DigitalGlobe of Longmont, Colorado, to perform trade studies, develop preliminary designs, and develop business plans. The formulation phase culminated in November with a preliminary design review conducted by each company. NASA worked with each company during the period of performance to refine LDCM data specifications, define calibration requirements, and craft a data policy that protects both the scientific mission and commercial interests. NASA at the same time used the formulation phase results to help write an RFP for the second step of the procurement process, the implementation phase.

The implementation phase RFP was release on January 06, 2003. Following the receipt and evaluation of proposals, NASA will select a single commercial operator to deliver LDCM data to the USGS for a period of five yeas beginning in March 2007. The contract will include a costed option for an additional five years of data. The LDCM Project Science Office within the LTP has worked closely with the GSFC Landsat Project Office on all phases and aspects of the LDCM data procurement process. In particular, LTP scientists were heavily involved in the definition of the LDCM data specifications, the calibration and validation requirements, and the data policies. This involvement will continue through the implementation phase.

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NPOESS Preparatory Project (NPP)

The NPOESS Preparatory Project (NPP) will launch in 2006 to maintain continuity of certain environmental data sets that were initiated with NASA's Terra and Aqua satellites. It also provides risk reduction for the operational National Polar-Orbiting Operational Environmental Satellite System (NPOESS) scheduled for launch in 2009. NPOESS is designed to supply weather forecasting data to the nation's operational agencies (NOAA and the U.S. Air Force), and is managed by the Interagency Program Office (IPO, a joint agency office composed of NOAA, NASA and the U.S. Air Force members).

The NPP satellite will carry four sensors, including the Visible Infrared Imaging Radiometer Suite (VIIRS), the Cross-track Infrared Sounder (CrIS), the Advanced Technology Microwave Sounder (ATMS) and the Ozone Mapping and Profiler Suite (OMPS). See Figure 26. The addition of a fifth sensor, the Clouds and Earth’s Radiant Energy System (CERES), is under consideration. The VIIRS sensor is a 22-band wide field-of-view imaging sensor similar to EOS MODIS. The CrIS and ATMS sensors will work together to provide atmospheric temperature and moisture profiles. The OMPS system, with both nadir and limb-looking sensors, will provide both the ozone total column and vertical profiles.

NPP will launch in late 2006 into an 824 km orbit with a 10:30 equator crossing time at the descending node. The spacecraft will provide direct-to-ground transmission of stored mission instrument data, and also provide direct broadcast of real-time instrument data. Spacecraft flight operations and the spacecraft operations control center will be managed by Northrop Grumman, the NPOESS Shared System Performance Responsibility (SSPR) contractor.

The NPP operational products are designed to meet the needs of NASA, NOAA and the Air Force. The NPOESS Interface Data Processing Segment (IDPS), also provided by IPO/SSPR, will provide pseudo-operational processing of NPP instrument data for the user agencies. The products directly address 12 of the 23 NASA Earth Science Enterprise key research questions, and provide

16 of the 24 key EOS long-term measurements. NASA will provide additional ground processing capability to the research community for generation of additional research products, such as calibration/validation products and higher-level climate data records. Short- and long-term archive and distribution capabilities to support funded research will also be provided.

NASA currently supports NPP science through its Project Science Group (PSG) and through participation on IPO's Operational Algorithm Teams. In early 2003, NASA will solicit an NPP Science Team to help with sensor and product testing, and to evaluate research needs for additional products. Later, a second team may be solicited to develop climate data records.

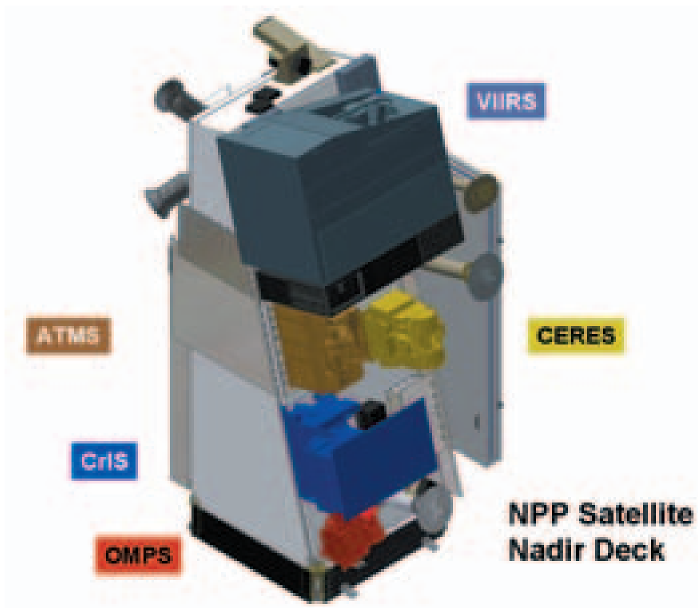

Figure 30. NPP Instruments

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International Programs

Laboratory personnel over the past ten or more years have taken on management or coordination roles in major international field campaigns. These field campaigns involve interdisciplinary scientists from NASA, other federal agencies, universities, and international partners performing in-depth research into various ecosystems such as grassland prairies in Kansas (FIFE), northern hardwoods in Maine (FED), and boreal forest in Canada (BOREAS). Web sites: http://boreas.gsfc.nasa.gov/ and http://fedwww.gsfc.nasa.gov/. Below are two such activities: LBA (tropical forest in Amazonia) and a new project, the Northern Eurasia Earth Science Partnership Initiative (NEESPI)

The Large Scale Biosphere-Atmosphere Experiment in Amazonia (LBA)

The Large Scale Biosphere-Atmosphere Experiment in Amazonia or LBA Project is led by the Ministry of Science and Technology in Brazil with international cooperation from NASA and the European Union. The LBA Project is composed of various independently funded components. NASA currently funds the LBA-ECO and LBA-HYDROMET components, which are both managed at the Goddard Space Flight Center. LBA-ECO activities have been continuing since a formal agreement was signed in 1998 and field infrastructure was put in place to start field activities in 1999 (see Figure 31 and 32).

Figure 31. Both triangular radio towers (as shown) and walk-up platform towers have been erected at numerous sites within the forests in the Amazon basin to facilitate measurements of atmospheric gas profiles, water vapor, etc. These measurements of seasonal and interannual variation effects on biosphere-atmosphere fluxes will run for 3 to 5 years.

Since the completion of the implementation phase in 2001, the LBA-ECO Field Operations Team has taken on a stronger role in terms of logistical, administrative, and technical support for the investigators working in the field in Brazil. The high level of scientific activity made it necessary to open a new support office in Santarem. The emphasis of this new office is to support long-term researchers and students. In 2002, a new flux tower was put into operational use in a recently logged area. Data from this new tower will be used to compare fluxes with a neighboring tower in an undisturbed forested area. The Project Office also continues to maintain the various tower sites, base camps, and office facilities for the LBA-ECO researchers, as well as a large fleet of vehicles and other support equipment.

After three years of data collection, LBA is maturing and the collaboration in the project between American and Brazilian scientists is producing excellent scientific results. The LBA-ECO Project Office at Goddard provided extensive help in organizing the Second International LBA Science Conference in Manaus, Brazil (July 7-10, 2002). Staff members created a web site to facilitate conference registration, information dissemination, as well as abstract submission, review, and acceptance. The meeting was attended by hundreds of participants, including prominent scientists reporting results from their LBA research. The Project Office at Goddard worked with their Brazilian counterparts to provide logistical support during the meeting and participated in the LBA press and media support group to help disseminate conference results to media outlets.

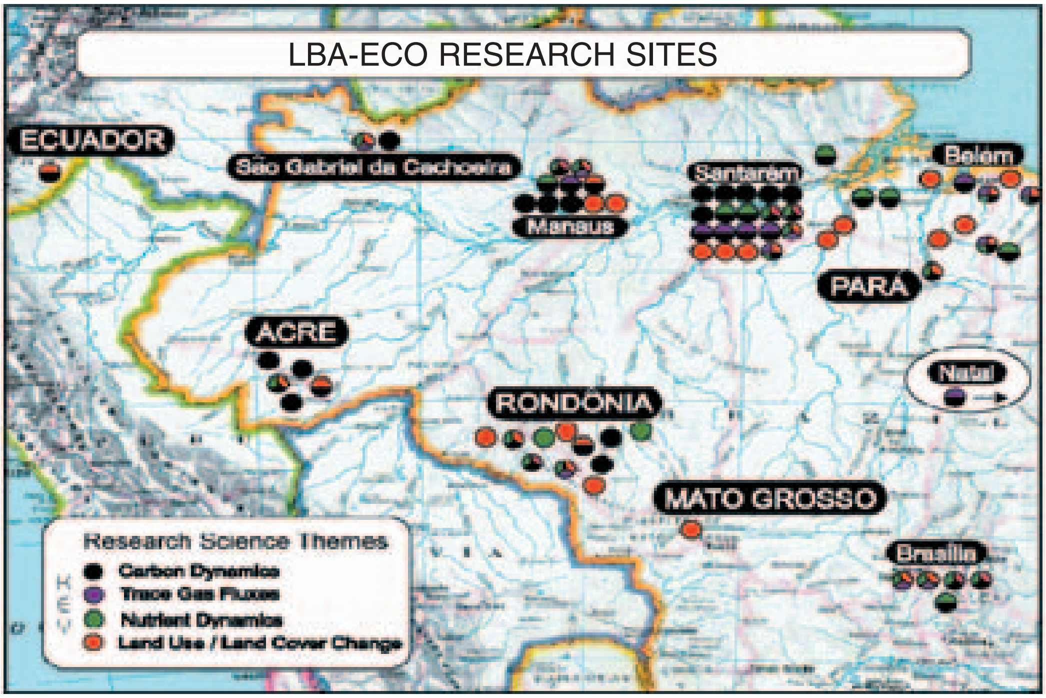

Figure 32. The geographical distribution of LBA-ECO research sites throughout the Amazon basin is illustrated in this map, along with a summary of the range of research themes being conducted at each location.

Some of the results presented at the conference indicate that fires in the Amazon region produce an overabundance of aerosols that serve as condensation nuclei, reducing the amount of condensed water on individual nuclei and inhibiting rain events in the Amazon region. Results from a study in a wetland area suggest that a greater amount of carbon is released from rivers than previously thought. New research proposed in Phase 2 at Ilha Bananal will provide further evidence on the nature and origin of wetland fluxes.

In 2002, the LBA-ECO Project Office prepared comprehensive reports of the LBA-ECO Phase 2 proposals for reviewers to make preliminary selections. The selected proposals strike a good balance between continuing data collection at existing sites in order to build up long-term data sets and starting new lines of research in other environments in the Amazon where new instrumentation will be installed.

The LBA-Air-ECO science teams have made significant progress in planning their flights and preparing for their campaigns in 2003. However, the lack of a signed implementing agreement for LBA-Air-ECO has hampered efforts to prepare for the Air-ECO activities in Brazil.

The LBA-ECO Project Office created a new website, coinciding with the start of Phase 2. The organization and layout of the website were greatly improved, making it easier for the science team to communicate with LBA-ECO logistics support staff, the LBA-ECO Project Office, the LBA Central Office, NASA program managers, and Brazil's Ministry of Science and Technology. As a result of adopting open-source software using Linux and mySQL, the cost savings to NASA was estimated to be $50,000 per year.

LBA-ECO collaborated with Brazil's Ministry of Science and Technology and other Brazilian agencies to support the LBA Student Conference in Belém (March 16-21, 2002). The conference gave students that support LBA research the opportunity to present the results of their work to LBA investigators and other students.

As Phase 1 of LBA-ECO has ended, progress has been made in getting data sets registered into the LBA data system. From November 2001 to December 2002, total registrations (data sets and posters) in Beija-flor (the metadata search and data retrieval system for LBA) increased from 323 to 586, an increase of 81% -- 73% of which were contributed by LBA-ECO funded investigations. Furthermore, registration of actual data sets (excluding posters) increased from 231 to 379 data sets: an increase of 148 data sets -- 91% of which were contributed by LBA-ECO funded investigators. This number is particularly significant given that LBA-ECO investigation teams compose only about half of all LBA investigation teams.

During the past year, communications between the LBA-ECO Project Office and the LBA Central Office in Brazil have improved significantly. The two offices have bi-weekly teleconferences to discuss issues related to LBA-ECO activities in Brazil and how to work with the Central Office by openly sharing information to resolve problems mutually.

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The Northern Eurasia Earth Science Partnership Initiative (NEESPI)

Various NASA funded investigations and others in recent years have shown that the circumboreal region of the Earth has been warming up. One of the results has been a gradual increase in vegetation lushness and growing season in parts of the Northern Hemisphere. However, Eurasia appears to be especially impacted and greening even more than North America, with more lush vegetation for longer periods of time. Evidence continues to mount that the northern latitude warming during the past few decades has been affecting the structure and function of terrestrial ecosystems in high-latitude regions and may be affecting regional and global climate systems.

Northern Eurasia is also a major player in the global carbon budget, particularly the boreal forests and peatlands, as circumpolar boreal forest systems alone contain more than 5 times the carbon of temperate forests and almost double the amount of carbon in the World's tropical forests. Climate warming induces natural terrestrial processes to release more carbon dioxide and methane, a particular concern in the boreal zone where more than 60% of the carbon exists as peat. Much of the peat is imbedded in permafrost, which may be melting. Additionally, a warmer boreal zone climate is resulting in more frequent and larger fires in all of the terrestrial ecosystems. Reasonable models speculate that these effects could eventually lead to a "runaway greenhouse" scenario. Aforestation and reforestation may not help either, as recent research has shown that in large parts of northern Eurasia, the decrease in surface albedo by forestation is as important as carbon sequestration in its forcing of climate. As a result, forest carbon sinks in these regions could exert a much smaller cooling influence than expected, or even exert an overall warming influence.

As a result, interest within the global change research community has grown dramatically in the past decade. Northern Eurasia is a vast area about which relatively little is known in the Western scientific world, and as the region where temperature rise is expected to be the greatest, feedbacks to the atmosphere are potentially large. These effects coupled with the dramatic political shifts throughout this region in the early 1990's and the attendant potential for rapid economic development, create the possibility for large and significant biological, climatic and socioeconomically coupled land use changes throughout this region.

Science issues for northern Eurasia are growing in global importance not only in relation to climate change and carbon, but also for aquatic, arid, and agricultural systems, snow and ice dynamics, and human health issues among others. For example, these changes have substantial implications for human livelihoods in high-latitude regions and elsewhere through effects on subsistence resources (e.g., reindeer populations and their movements), commercial fisheries resources, infrastructure, and industrial activity; and they may have consequences for the functioning of the entire Arctic System. Some of the potential effects include the way that water and energy are exchanged with the atmosphere, radiatively active gases are exchanged with the atmosphere, and freshwater is delivered to the Arctic Ocean. Socioeconomic changes during the past 10 years are found in the death rate of men increasing by more than six times and of women by nineteen times with the current average life expectancy of 37 years for the native peoples in the Russian part of northern Eurasia.

The International Geosphere Biosphere Program (IGBP) reported this year that the circumboreal region containing northern Eurasia is one of the critical "Switch and Choke" points in the Earth system, and proposed that what is needed for this region is a "glue" to fit multidisciplinary pieces of research together into a fully integrated, regional program. Generally, small and/or "detached" research projects are conducted in this huge, biologically, hydrologically, and climatically diverse and complicated region, and the countries and institutions in this region generally do not have the expertise and/or resources to independently conduct and coordinate the needed research.

At the 12th Meeting of the U.S.-Russian Earth Science Joint Working Group (ESJWG) held in Moscow in October 2002, NASA and the Russian Academy of Sciences formally agreed to work together to develop a program of research that is called the Northern Eurasia Earth Science Partnership Initiative, or the NEESPI. The mission of the NEESPI is to ". . . identify the critical science questions and establish a program of coordinated research on the state and dynamics of terrestrial ecosystems in northern Eurasia and their interactions with the Earth's climate system to enhance scientific knowledge and develop predictive capabilities to support informed decision-making and practical applications."

The agreement followed more than two years of informal discussions and planning between U.S. and Russian scientists and administrators across Russia and in the U.S. These discussions culminated in the first formal NEESPI Workshop, which was held at the Presidium of the Russian Academy of Sciences in Moscow in February 2002; and involved more than 50 participants from many Russian governmental agencies and private organizations as well as representatives from the U.S. and Canada.

The NEESPI provides a framework for currently funded NASA Earth Science investigations (>20 studies during the past 3 yrs.) to improve their sharing of resources and data and information, and to facilitate research collaborations and resolving Russian bureaucratic issues, and to promote study integration and planning. The NEESPI currently assists in seeking and providing funding for short term research projects (over the next 1-2 yrs) and seeks to provide the "glue" (longer term, multi-source funding) for developing an integrated understanding of the Earth system for this part of the globe.

The NEESPI leadership is working with other U.S. agencies/scientists and international partners to develop a formal NEESPI Science Plan for an integrated, interdisciplinary Earth science project that will be viable for securing funding from multiple NASA programs and other national and international partner organizations to subsequently implement a program of research to address key science questions of global significance in Northern Eurasia. The first NEESPI Science Plan Workshop is scheduled for April 2003 in Suzdal, Russia, and the publication of the NEESPI Science Plan is expected in the first quarter of 2004 – just prior to the first Northern Eurasia Earth Science Conference to be held in Ann Arbor, Michigan in May 2004. The goal is to have a full NEESPI Project Implementation in two, three-year phases to begin in CY2005.

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Refereed Journal Publications

Amr, S., M.B. Bollinger, M. Myers, R.G. Hamilton, S.Weiss, M. Rossman, L. Osborne, S. Timmins, **D.S. Kimes**, **E.R. Levine**, C.J. Blaisdell. Asthma and its environmental triggers in Baltimore City Public Schools., Annals of Asthma, Allergy, and Immunology, 90:34-44, 2002

Anyamba, A., K.J. Linthicum, **R. Mahoney,** and **C.J. Tucker**, Mapping Potential Risk of Rift Valley fever outbreaks in African Savannas using Vegetation Index Time Series Data, *Photogrammetic Engr. & Remt.Sens., 68*, No. 2, 137-145, 2002.

Anyamba, A., **C.J. Tucker,** and **R. Mahoney**, From El Niño to La Niña: Vegetation response patterns over East and Southern Africa during 1997-2000 period, *J. Climat,15, 3096-3103, 2002.*

Birkett, C.M., L.A.K. Mertes, T. Dunne, M. Costa, and M. Jasinski,, Altimetric Remote Sensing of the Amazon: Application of Satellite Radar Altimetry, *J. Geophys.Res.,* 107 (D20), 10.1029/2001JD000609, 4th September, 2002.

Blaisdell, C., M.B. Bollinger, S. Timmins, **D. Kimes, E. Levine**, M. Myers, and S. Weiss. Temporal and Spatial Trends in Pediatric Asthma Hospitalization in Maryland. *J. of Asthma*, 39(7):567-575, 2002**.**

Bogaert J., Zhou L., **Tucker C.J.,** Myneni R.B., and Ceulemans R., Evidence for a persistent and extensive greening trend in Eurasia inferred from satellite vegetation index data. *J.Geophys. Research-Atmospheres* 107(D11): DOI 10.1029/2001JD001075, 2002.

Bounoua L., R. S. DeFries, **G. J. Collatz**, P. S. Sellers, H. Khan, Effects of land cover conversion on climate, *Climate Change 52*, 29-64, 2002.

Chang CI, Chiang SS, **Smith JA**, et al., Linear spectral random mixture analysis for hyperspectral imagery, IEEE T GEOSCI REMOTE 40 (2): 375-392 FEB 2002

Chin, M., P. Ginoux, **S. Kinne**, O. Torres, **B. N. Holben**, B. N. Duncan, R. V. Martin, J. A. Logan, A. Higurashi, and T. Nakajima, Tropospheric aerosol optical thickness from the GOCART model and comparisons with satellite and sunphotometer measurements, *J. Atmos. Sci., 59*, 461-483, 2002.

Christopher, S.A., J. Zhang, **B.N. Holben**, and S.-K. Yang, GOES-8 and NOAA-14 AVHRR retrieval of smoke aerosol optical thickness during SCAR-B, *Int. J. Remote Sensing, 23*, 4931-4944, 2002.

Coe, M.T., M.H. Costa, A. Botta, and **C.M. Birkett**, Long-term simulations of discharge and floods in the Amazon Basin, *J. Geophys. Res*., 107 (D20), 10.1029/2001JD000740, 4th September, 2002.

DeFries R. S., **L. Bounoua**, **G. J. Collatz**, Human modification of the landscape and surface climate in the next 50 years. *Global Change Biology 8,* 438-454, 2002

Dickinson R. E., J. A. Berry, G. B. Bonan, **G. J. Collatz**, C. B. Field, I. Y. Fung, M. Goulden, W. A. Hoffman, R. B. Jackson, R. Myneni, P. J. Sellers, M. Shaikh, Nitrogen Controls on climate model evapotranspiration, *Journal of Climate 15*, 278-295, 2002.

Drake, J.B., R.O. Dubayah, D.B. Clark, **R.G. Knox, J.B. Blair,** M.A. Hofton, R.L. Chazdon, J.F. Weishampel, and S.D. Prince, Estimation of tropical forest structural characteristics using large-footprint lidar, *Remote Sensing of Environment 79:* 305 - 319, 2002.

Drake, J.B., R.O. Dubayah, **R.G. Knox,** D.B. Clark, and **J.B. Blair**, Sensitivity of large-footprint lidar to canopy structure and biomass in a neotropical rainforest, *Remote Sensing of Environment 81:* 378 - 392, 2002.

Dubovik, O., **B.N.Holben**, **T.F.Eck**, **A.Smirnov**, Y.J.Kaufman, M.D.King, D.Tanre, and **I.Slutsker**, Variability of absorption and optical properties of key aerosol types observed in worldwide locations, *J.Atm.Sci*., *59*, 590-608, 2002.

Dubovik, O., B. N. Holben, **T. Lapyonok**, A. Sinyuk, M. I. Mishchenko, P. Yang and **I. Slutsker**, Non-spherical aerosol retrieval method employing light scattering by spheroids, *Geophys. Res. Lett.*, 10.1029/2001GL014506,24 May 2002.

Guillevic P., R. D. Koster, M. J. Suarez, **L. Bounoua, G. J. Collatz**, S. O. Los, S. P. P. Mahanama, Influence of the interannual variability of vegetation on the surface energy balance - A global sensitivity study, *Journal of Hydrometeorology 3*, 617-629, 2002

Hicke J.A., Asner G.P., Randerson J.T., **Tucker C.J., Los S.O**., Birdsey R., Jenkins J.C., Field C., Holland E., Satellite-derived increases in net primary productivity across North America, 1982-1998, *Geophysical Research Letters* 29(10):10.1029 2001GL013578, 2002.

Hicke J.A., Asner G.P., Randerson J.T., **Tucker C.J., Los S.O**., Birdsey R., Jenkins J.C., Field C., Trends in North American net primary productivity derived from satellite observations, 1982-1998 *Global Biogeochemical Cycles* 16(2): 10.1029/2001GB001550, 2002.

Ichoku, C., R. Levy, Y.J., Kaufman, L.A. Remer, R.-R. Li, V.J. Martins, **B.N. Holben**, N. Abuhassan, **I. Slutsker, T.F. Eck**, C. Pietras, Analysis of the performance characteristics of the five-channel Microtops II Sun photometer for measuring aerosol optical thickness and precipitable water vapor, *J. Geophys. Res*., 10.1029/2001JD001302, 12 July 2002.

Ichoku, C., D. A. Chu, S. Mattoo, Y. Kaufman, L.A. Remer, D. Tanre, **I. Slutsker** and **B.N. Holben**, A spatio-temporal approach for global validation and analysis of MODIS aerosol products, Geophys. Res. Lett., 29, No 12, 10.1029/2001GLO13206,2002.

Justice, C. O., **Giglio, L**., Korontzi, S., Owens, **J., Morisette**, **J. T., Roy, D., Descloitres**, J., Alleaume, S., Petitcolin, F., & Kaufman, Y., The MODIS Fire Products. *Remote Sensing of Environment., 83*, 244–262, 2002.

Justice C. O., J. R. G. Townshend, **E. F. Vermote**, **E. Masuoka**, **R. E. Wolfe**, **N. Saleous**, **D.**

P. Roy, **J. T. Morisette**, An overview of MODIS Land data processing and product status, *Remote Sensing of Environment, 83* (1-2), 3-15 2002.

Kaufman, Y.J., **O.Dubovik**, **A.Smirnov**, and **B.N.Holben**, Remote sensing of non-aerosol absorption in cloud free atmosphere, *Geophys. Res. Lett., 29*(18), 1857, doi:10.1029/2001GL014399, 2002.

Kaufman, Y.J., D. Tanre, **B.N. Holben**, S. Mattoo, L.A. Remer, **T.F. Eck**, J. Vaughan, and B. Chatenet, Aerosol radiative impact on spectral solar flux at the surface, derived from principal-plane sky measurements, *J. Atmos. Sci., 59*, 635-646, 2002.

Kharuk V.I., **K.J Ranson**., V.V Kuzmichev., T.A. Burenina, A. Yu. Tikhomirov, and S.T. Im, An analysis of temporal dynamics of the Siberian silkmoth outbreaks, *Russian J. of Remote Sensing*, 4: 1-12, 2002.

Kimes, D., J. Gastellu-Etchegorry, and P. Esteve, 2002, "Recovery of Forest Canopy Characteristics Thorough Inversion of a Complex 3D Model", *Remote Sensing of Environment, 79*:320-328.

Little, E.E., R.D. Calfee, D.L. Fabacher, C. Carey, V.S. Blazer, and **E.M. Middleton**, Effects of ultraviolet-B radiation on toad early life stages, Environmental Science and Pollution Research, online electronic publication, 10 pp., 6/30/2002

Lefsky, M.A., W.B. Cohen**, D.J. Harding**, G.G. Parker, S.A. Acker, and S.T. Gower, Lidar remote sensing of aboveground biomass in three biomes, *Global Ecology and Biogeography*, 11(5): 393-399, 2002.

Lefsky, M.A., W.B. Cohen, G.G. Parker, and **D.J. Harding**, Lidar remote sensing for ecosystem studies, *Biosciences*, 52(1), 19-30, 2002.

Lobell D.B., Hicke J.A., Asner G.P., Field C.B., **Tucker C.J., Los S.O.** Satellite estimates of productivity and light use efficiency in United States agriculture, 1982-98, *Global Change Biology* 8(8):722-735, 2002.

Los, S. O., **C. J. Tucker**, **A. Anyamba**, M. Cherlet, **G. J. Collatz**, **L. Giglio**, **F. G. Hall** and J. Kendall, *The Biosphere: A Global Perspective***,** Chapter 5, **In** A. K. Skidmore (Editor) Environmental Modelling with GIS and Remote Sensing, pp. 70-96, Taylor & Francis, New York, 2002.

Morisette, J.T.. Privette, J.L., and Justice, C.O., A framework for the validation of MODIS land products, *Remote Sensing of Environment*, 83 (1-2) 77-96, 2002

Myneni, R.B., Y. Knyazikhin, **J.L. Privette**, J. Glassy, Y. Tian, Y. Wang, S. Hoffman, X. Song, Y. Zhang, G.R. Smith, A. Lotsch, M. Friedl, **J.T. Morisette**, P. Votava, R.R. Nemani, and S.W. Running, Global products of vegetation leaf area and fraction absorbed PAR from year one of MODIS data, *Remote Sensing of Environment*, 83 (1-2) 214 - 231, 2002.

O'Neill, N.T., **T.F.Eck**, **B.N.Holben**, **A.Smirnov**, A.Royer, and Z.Li, Optical properties of boreal forest fire smoke derived from Sun photometry, *J. Geophys. Res., 107(D11)*, 10.1029/2001JD000877, 2002.

Otter, L.B., R.J. Scholes, P. Dowty, **J.L. Privette**, K. Caylor, S. Ringrose, M. Mukelabai, P. Frost, O. Totolo, E.M. Veenendaal, The SAFARI 2000 wet season campaigns, *S. African J. Sci*., *98(3/4),* 131-137, 2002

Otterman, J., A. Karnieli, **T. Brakke**, D. Koslowsky, H.-J. Bolle, D. Starr, and H. Schmidt, Desert scrub optical density and spectral-albedo ratios of impacted-to-protected areas by model inversion, *Int. J. Remote Sensing, 23*, 3959-3970, 2002.

Petitcollin F. and **Vermote E. F**., 2002, Land Surface Reflectance, Emisivity and Temperature from MODIS Middle and Thermal Infrared data, Remote Sensing Of Environment, 83,1-2,112-134.

Privette, J.L., R.B. Myneni, Y. Knyazikhin, M. Mukelabai, Y. Tian, Y. Wang, G. Roberts and S. Leblanc, Early spatial and temporal validation of MODIS LAI in the Southern Africa Kalahari, *Remote Sens. Environ*., *83*, 232-243, 2002.

Qin, Wenhan, S.A.W. Gerstl, **D.W. Deering** and N.S.Goel, Characterizing leaf geometry for grass and crop canopies from hotspot observations: A simulation study. *Remote Sens. Environ.* 80 (1), 100-113, 2002.

Ouaidrari, H., Goward, S.N. , Czajkowski, K.P. , Sobrino, J.A**., Vermote, E.F.**, 2002, Land Surface Temperature Estimation from AVHRR Thermal Infrared Measurements: An Assessment for the AVHRR Land Pathfinder II Data Set, Remote Sensing of Environment, 81, 114-128.

Randerson J. T., **G. J. Collatz**, J.E. Fessende, A. D. Muno, C. J. Still, J. A. Berry, I. Y. Fung, N. Suits, A. S. Denning, A possible global covariance between terrestrial gross primary production and 13C discrimination: Consequences for the atmospheric 13C budget and its response to ENSO, *Global Biogeochemical Cycles , 16*, 1136, doi:10.1029/2001GB001845, 2002.

Remer, L.A., D.Tanre, Y.J.Kaufman, C.Ichoku, S.Mattoo, R.Levy, D.A.Chu, **B.N. Holben**, **O.Dubovik**, **A.Smirnov**, J.V.Martins, R.-R.Li, Z.Ahmad, Validation of MODIS aerosol retrieval over ocean, *Geophys.Res.Lett*., *29(12)*, 10.1029/2001GL013204, 2002.

Rogers, D.J, Myers, M. F**., Tucker, C.J.,** Smith, P.F., White, D. J., Backenson, P.B., Eidson, M., Kramer, L.D., Baaker, B., and Hay, S**.,** Predicting the distribution of West Nile Fever in North America using satellite sensor data. *Photogram. Eng. Remote Sens.* 68:112-136, 2002.

Rosenqvist, Å., **C.M. Birkett**, E. Bartholomé, and G. De Grandi, Using satellite altimetry and historical gauge data for validation of the hydrological significance of the JERS1 SAR (GRFM) mosaics in Central Africa, *Int. J. Rem. Sens.*, 23 (7), 1283-1302, 2002.

Roy D. P., **J. S. Borak**, **S. Devadiga**, **R. E. Wolfe**, **M. Zheng**, **J. Descloitres**, The MODIS Land product quality assessment approach, *Remote Sens. Environ., 83* (1-2), 62-76, 2002.

Sabol, D. E., Gillespie, A. R., Adams, J. B., Smith, M. O., and **Tucker, C. J.,** Structural stage in Pacific Northwest forests estimated using simple mixing models of multispectral images. *Remote Sens. Environ.* 80:1-16, 2002.

Schaaf, C.B., Gao, F., Strahler, A.H., Lucht, W., Li, X., Tsang, T., Strugnell, N.C., Zhang, X., Muller, J-P., Lewis, P., Barnsley, M., Hobson, P., Disney, M., Roberts, G., Dunderdale, M., Doll, C., d'Entremont, R, P., Hu, B., **Privette, J.L.**, and **Roy, D**., The at-launch MODIS BRDF and albedo science data product, *Remote Sens. Environ.*, *83*, 135-148, 2002.

Schafer, J.S., T. F. Eck, B. N. Holben, P. Artaxo, M. A. Yamasoe, and A. S. Procopio, Observed reductions of total solar irradiance by biomass-burning aerosols in the Brazilian Amazon and Zambian Savanna, *Geophys. Res. Lett., 29*, 1823, doi:10.1029/2001GL014309, 2002.

Schafer , J.S., B.N. Holben, T.F. Eck, M.A. Yamasoe and P. Artaxo, Atmospheric effects on insolation in the Brazilian Amazon: Observed modification of solar radiation by clouds and smoke and derived single scattering albedo of fire aerosols, *J. Geophys. Res*., 107, 8074, doi:10.1029/2001JD000428, 2002.

Shabanov, N.V., Zhou, L., Knyazikhin, Y., Myneni, R.B. and **Tucker, C.J.,** Analysis of interannual changes in northern vegetation activity observed in AVHRR data from 1981 to 1994. *IEEE Trans. Geosci. Remote Sens.* 40:115-130, 2002.

Smirnov, A., **B.N.Holben**, **T.F.Eck**, **I.Slutsker**, B.Chatenet, and R.T.Pinker, Diurnal variability of aerosol optical depth observed at AERONET (Aerosol Robotic Network) sites, *Geophys. Res. Lett.* , *29* (23), 2115, doi:10.1029/2002GL016305, 2002.

Smirnov, A., B.N.Holben, Y.J.Kaufman, **O.Dubovik**, **T.F.Eck**, **I.Slutsker**, C.Pietras, and R.Halthore, Optical properties of atmospheric aerosol in maritime environments, *J.Atm.Sci*., *59*, 501-523, 2002.

Smirnov, A., **B.N.Holben**, **O.Dubovik**, **N.T.O'Neill**, **T.F.Eck**, D.L.Westphal, A.K.Goroch, C.Pietras, and **I.Slutsker**, Atmospheric aerosol optical properties in the Persian Gulf region, *J. Atm. Sci., 59*, 620-634, 2002**.**

Sun, G., K.J. Ranson and V.I. Kharuk, Radiometric slope correction for forest biomass estimation from SAR data in the Western Sayani Mountains, Siberia. *Remote Sensing of Environment*, 79: 279-287, 2002.

Swap, R.J., H. Annegarn, J.T. Suttles, J. Haywood, M.C. Helmlinger, C. Hely , P.V. Hobbs, **B.N. Holben** , J. Ji , M.D. King , T. Landmann , W. Maenhaut, L. Otter, B. Pak , S.J. Piketh , S. Platnick, **J.L. Privette**, et al., The SAFARI 2000 dry season campaigns, *S. African J. Sci., 98(3/4)*, 125-130, 2002

Takamura, T, T. Nakajima, O **Dubovik, B. Holben, S. Kinne**., Single-Scattering albedo and radiative forcing of various aerosol species with a global three-dimensional model*, J. of Climate*, 15,4, 333-352, 2002.

Tian, Y., C.E. Woodcock, Y. Wang, **J.L. Privette**, et al., Multiscale analysis and validation of the MODIS LAI product. I. Uncertainty Assessment, *Remote Sens. Environ.*, *83*, 414-430, 2002.

Tian, Y., C.E. Woodcock, Y. Wang, **J.L. Privette**, et al., Multiscale analysis and validation of the MODIS LAI product over Maun, Botswana. II. Sampling Strategy, *Remote Sens. Environ.*, *83*, 431-441, 2002.

Tucker, C. J., Wilson, J. M., **Mahoney, R., Anyamba, A**., Linthicum, K. J., and Myers, M., 2002. "Climatic and Ecological Context of Ebola Outbreaks". *Photogrammetric Engineering and Remote Sensing*, (2002) 68, N0. 2,147-152.

Ungar, S., Overview of the Earth Observing One (EO-1) Mission, *IEEE Geosci. & Remote Sens. Newsletter, v. 123*, 3-6.

Vermote, E. F. and **Roy, D.P**.,2002, Land Surface Hot-Spot observed by MODIS over Central Africa, *International Journal of Remote Sensing*, Cover Letter, (11): 2141-2143.

Vermote E.F., **El Saleous N**, Justice C, 2002, Atmospheric correction of the MODIS data in the visible to middle infrared: First results, Remote Sens. Environ., 83, 1-2, 97-111.

Wolfe R. E., M. Nishihama, A. J. Fleig, J. R. Kuyper, D. P. Roy, J. C. Storey, F. S. Patt, Achieving sub-pixel geolocation accuracy in support of MODIS land science, *Remote Sensing of Environment, 83* (1-2), 31-49, 2002.

Zhao, T.X.-P., L.L.Stowe, **A. Smirnov**, D. Crosby, J. Sapper, and C.R.McClain, Development of a global validation package for satellite oceanic aerosol retrieval based on AERONET sunphotometer observations and its application to NOAA/NESDIS operational aerosol retrievals, *J.Atm.Sci*., *59*, 294-312, 2002.

Proceedings Papers, NASA Technical Documents, etc.

Arvidson, T., **R. Irish, B. L. Markham, D. L. Williams**, J. Feuquay, J. Gasch, and S. N. Goward, Validation of the Landsat 7 Long Term Acquistion Plan, In Proc of the Pecora 15, Held 10-15 November 2002, Denver, CO, ASPRS, Bethesda, MD, 2002.

Campbell, P.K.E., **E.M. Middleton**, **L.A. Corp**, J.E. McMurtrey III, M.S. Kim, **E.W. Chappelle**, and **L.M. Butcher**, Contribution of chlorophyll fluorescence to the reflectance of corn foliage, Proceedings, International Geoscience and Remote Sensing Symposium, IGARSS 2002, Toronto, Canada, 3 pp., CD-ROM 6/24/2002.

Corp, L.A., **E.M. Middleton**, J.E. McMurtrey, **P.K. Entcheva Campbell**, M.S. Kim, **E.W. Chappelle,** and **L.M. Butcher**, Fluorescence imaging techniques for monitoring vegetation, Proceedings, International Geoscience and Remote Sensing Symposium, IGARSS 2002, Toronto, Canada, 3 pp., CD-ROM 6/24/02.

Descloitres, J., R. Sohlberg, J. Owens, **L. Giglio**, C. Justice, M. Carroll, **J. Seaton**, M. Crisologo, M. Finco, K. Lannom, and T. Bobbe, 2002: The MODIS Rapid Response Project. Proceedings of the IEEE International Geoscience and Remote Sensing Symposium (IGARSS'02).

Dorofeev F.V., D.M.Kabanov, M.V.Panchenko, S.M.Sakerin, **A.Smirnov**, S.A.Turchinovich, **B.N.Holben**, and N.N.Shchelkanov, AROSIBNET: preliminary results and prospective, Symposium on Aerosols in Siberia, Tomsk, Russia, November 24-27, 2002.

Holben, B. N., O. Dubovik, T. F. Eck, A. Smirnov, A. Vermeulen, I. Slutsker, AERONET: Ground-based aerosol characterization, Proceedings of a Workshop: "Air Pollution as a Climate Forcing", East-West Center, Honolulu, April 29-May 3, 2002, pp. 77-78.

Kharuk V. I. and **K.J. Ranson**, Landsat-7 in evaluation of oilfield exploitation impact on the south Evenkiya larch dominant communities. In Proceedings of SPIE's Symposium "Remote Sensing of the Atmosphere, Ocean, Environment, and Space". Vol. 4898. 23-27 October 2002, Hangzhou, China, 2002.

Kharuk, V.I.**K. J. Ranson**, V. Tret'yakova, and A. Shashkin, 2002. Reaction of the larch dominated communities on climate trends //In: Proceedings of an International Symposium "Improvement of Larch (Larix sp) for better growth, stem form and wood quality". France, Gap September 16-21. INRA, ed. L.E. Paques. Pp. 289-295.

Le Moigne, J., A. Cole-Rhodes, R. Eastman, T. El-Ghazawi, K. Johnson, S. Kaewpijit, N. Laporte, **J. Morisette**, N. Netanyahu, H. Stone and I. Zavorin, Multiple Sensor Image Registration, Image Fusion and Dimension Reduction of Earth Science Imagery, Proceeding of FUSION'2002, pp 999-1006, 2002.

Le Moigne, J., A. Cole-Rhodes, R. Eastman, K. Johnson, **J. Morisette**, N. Netanyahu, H. Stone and I. Zavorin, 2002, " Multi-Sensor Image Registration for On-the-Ground or On-Board Science Data Procesisng," Science Data Processing Workshop, SDP'2002, Greenbelt, January 2002, pp. 961-966.

Levine, E. and **D. Kimes**. Assessing Links between Ecosystem Health and Childhood Asthma. Proceedings of the Healthy Ecosystems, Healthy People Conference, Washington, DC., 2002.

Levine, E., J. Robin, and S. Riha, Using Satellite Imagery and GLOBE data to Model Soil Dynamics, Proc. 6th Annual GLOBE meeting, Chicago, IL., 2002. http://www.globe.gov/fsl/html/templ.cgi?model_soil&lang=en&nav=1

Levine, E., J. Robin, and N.Owe. Effects of Acid Rain on Soil pH, Proc. 6th Annual GLOBE meeting, Chicago, IL, 2002. http://www.globe.gov/fsl/html/templ.cgi?acid_soil&lang=en&nav=1

Levine, E. and J. Robin, Understanding Soil Color Patterns across the Globe", Proc. 6th Annual

GLOBE meeting, Chicago, IL, 2002.
http://www.globe.gov/fsl/html/templ.cgi?soilcolor_paterns&lang=en&nav=1

Lindsay, F.E. and **Masek, J**. (2002). A Tale of Two Cities: Characterizing Urban Growth Using Variable Resolution Remote Sensing Data. Proceedings for the Third International Symposium Remote Sensing of Urban Areas. Istanbul, Turkey. Vol.2, pp.591-599.

Markham, B. L., J.L. Barker, J.A. Barsi, **E. Kaita**, K.J. Thome, D.L. Helder, F. D. Palluconi, J.R. Schott, and P. Scaramuzza, Landsat-7 ETM+ radiometric stability and absolute calibration, In Proc. of SPIE/Europe, Held 23-27 September 2002, Crete, Greece, SPIE, Bellingham, WA, 2002.

Marshall, C.H., R.A. Pielke, Sn., **L.T. Steyaert**, T.M. Cronin, D.A. Willard, J.W. Jones, T.J. Smith III, and **J.R. Irons**, Impact of land-use management practices in Florida on the regional climate of South Florida, Conference Paper Presented at the 13th Symposium on Global Change and Climate Variations (online AMS Web Proceedings, Session J8.6, 3 pp.), 82nd Annual Meeting of the American Meteorological Society, Orlando FL, January 13-17, 2002.

McClain, C.F., **F.G. Hall, G.J. Collatz,** S.R. Kawa, W.W. Gregg, J.C. Gervin, **J.B. Abshire**, A.E. Andrews, C.D. Barnet, M.J. Behrenfeld, P.S. Caruso, A.M. Chekalyuk, L.D. Demaio, A.S. Denning, J.E. Hansen, F.E. Hoge, **R.G. Knox, J.G. Masek,** K.D. Mitchell, J.R. Moisan, T.A. Moisan, S. Pawson, M.M. Rienecker, S.R. Signorini, **C.J. Tucker**, *Science and Observation Recommendations for Future NASA Carbon Cycle Research,* National Aeronautics and Space Administration, Goddard Space Flight Center, Greenbelt, Maryland, NASA/TM - 2002 - 210009, 2002.

McMurtrey, J.E., **E.M. Middleton**, **L.A. Corp**, **P.K. Entcheva Campbell**, **L.M. Butcher**, **E.W. Chappelle**, and W.B. Cook, Fluorescence responses from nitrogen plant stress in 4 Fraunhofer band regions, Proceedings, International Geoscience and Remote Sensing Symposium, IGARSS 2002, Toronto, Canada, 3 pp., CD-ROM 6/24/02.

Middleton, E.M., **P.K. Entcheva Campbell**, J.E. McMurtrey, **L.A. Corp**, **L.M. Butcher**, and **E.W. Chappelle**, 'Red Edge' optical properties of corn leaves from different nitrogen regimes, Proceedings, International Geoscience and Remote Sensing Symposium, IGARSS 2002, Toronto, Canada, 3 pp., CD-ROM 6/24/02.

Middleton, E.M., J.E. McMurtrey, **P.K.E. Campbell**, **L.A. Corp**, **L.M.Butcher**, and **E.W. Chappelle,** Optical and fluorescence properties of corn leaves from different nitrogen regimes, Proceedings, 9th International Symposium on Remote Sensing (Remote Sensing 2002), SPIE- the International Society for Optical Engineering. Crete, Greece, Sept.23-27, 12 pp.

Nishihama M., **R. E. Wolfe**, **J. Kuyper**, **A. J. Fleig**, MODIS Geolocation Error Analysis Developments, IGARSS 2002: IEEE International Geoscience and Remote Sensing Symposium and 24th Canadian Symposium On Remote Sensing, Vols I-VI, Proceedings - Remote Sensing: Integrating Our View Of The Planet, 3661-3663, 2002.

Panchenko M.V., S.A.Terpugova, V.S.Kozlov, V.N.Uzjegov, S.M.Sakerin, D.M.Kabanov, B.D.Belan, M.Yu.Arshinov, T.M.Rasskazchikova, P.P.Anikin, G.I.Gorchakov, A.A.Isakov, V.M.Kopeykin, M.A.Sviridenkov, E.G.Semutnikova, **B.N.Holben**, and **A.Smirnov**, Echo of the Moscow region fires in the atmosphere of West Siberia, Symposium on Aerosols in Siberia, Tomsk, Russia, November 24-27, 2002.

Pedelty, J.A., Morisette, J.T., and Smith, J.A., "A Comparison of Landsat-7 ETM+ and EO-1 ALI Images Over Rochester, NY", SPIE, Aerosense Conference, Orlando FL, April 1-5, vol. 4725, p. 357-365, 2002.

Pinheiro, A.C., **J.L. Privette**, **R. Mahoney** and **C.J. Tucker** (2002), Directional effects in AVHRR Land Surface Temperature over Africa, Recent Adv. Quantitative Remote Sens. [J.A. Sobrino, ed.], Univ. of Valencia Publ., Spain, pp. 971-978.

Pinzón, J. E.,. "Using HHT to successfully uncouple seasonal and interannual components in remotely sensed data." SCI 2002 Proceedings, July 14 - 18, Orlando, FL, p. 78-83, 2002.

Privette, JL, Crystal B. Schaaf, Alan Strahler, Rachel T. Pinker, Michael J. Barnsley and **Jeffrey T. Morisette**, Summary of the International Workshop on Surface Albedo Product Validation, *EOS Earth Observer, 14(2),* 17-18, 2002

Ranson, K.J., K. Kovacs and G. Sun, Accounting for Topographic Slope Effects on Radar Backscatter in Siberian Forests, IGARSS02, Toronto, Canada, 2002.

Ranson, K.J., G. Sun, K.Kovacs and V.I. Kharuk, Utility of SARs for mapping forest disturbance in Siberia. IGARSS02, Toronto, Canada, 2002.

Sato, M., J. Hansen, **O. Dubovik, B. N. Holben**, Black carbon global climate forcing inferred from AERONET, Proceedings of a Workshop: "Air Pollution as a Climate Forcing", East-West Center, Honolulu, April 29-May 3, 2002, pp.106-108.

Schafer, J.S., T.F. Eck, B.N. Holben, P. Artaxo, M.A. Yamasoe, A.S. Procopio, Atmospheric Attenuation Of Total Solar Flux By Clouds and Aerosols At Six Amazonian Sites: 1999-2001, Second LBA International Scientific Conference, Manaus, Brazil, July 7-10, 2002.

Smid, J., **B. Markham**, P. Svzcek and P. Volf, Calibration, regression models and the web, In Proc. of SPIE/Europe, Held 23-27 September 2002, Crete, Greece, SPIE, Bellingham, WA, 2002.

Smirnov, A., **B.N.Holben**, **O.Dubovik**, L.Remer, **T.F.Eck**, and **I.Slutsker**, Atmospheric aerosol optical properties during PRIDE, PRIDE Data Workshop, Miami, FL, February 12-14, 2002.

Smirnov, A., **B.N.Holben**, R.Frouin, G.Fargion, **O.Dubovik**, **T.F.Eck**, and **I.Slutsker**, Atmospheric aerosol optical properties at the SIMBIOS/AERONET sites, SIMBIOS Science Team Meeting, Baltimore, MD, January 15-17, 2002.

Steyaert, L.T. and R.A. Pielke, Sr., Using Landsat-derived land cover, reconstructed vegetation, and atmospheric mesoscale modeling in environmental and global change research, Paper presented at the 53rd International Astronautical Congress (12 pp.), World Space Congress, Houston, Texas, October 10-19, 2002.

Sun, G., L. Rocchio, J. Masek, D. Williams, and K. J. Ranson, Chracterization of Forest recovery from fire using Landsat and SAR data, Proceedings of IGARSS'02, June 24-28, 2002, Toronto, Ontario, Canada.

Sun. G., K. J. Ranson, Modeling lidar and radar returns of forest canopies for data fusion, Proceedings of IGARSS'02, June 24-28, 2002, Toronto, Ontario, Canada.

S**un, G., J. Masek, D. Williams, L. Rocchio, and K. J. Ranson**, Forest and land-use mapping from temporal MODIS Data, Proceedings of IGARSS'02, June 24-28, 2002, Toronto, Ontario, Canada.

Sun, G. and K. J. Ranson, V. I. Kharuk, and **K. Kovacs**, Preliminary results in verification and evaluation of SRTM data, Proceedings of Advanced Workshop on InSAR Applications, pp. 7-13, Dec. 16-17, 2002, Hong Kong.

Ungar, S., Overview of the Earth Observing One (EO-1) mission, Proceedings of IGARSS'02, June 24-28, 2002, Toronto, Ontario, Canada., 568-571.